DS3500

Advanced Programming with Data

Northeastern University

John Rachlin
Northeastern University

Principles of Chess

The Top 35 Chess Principles

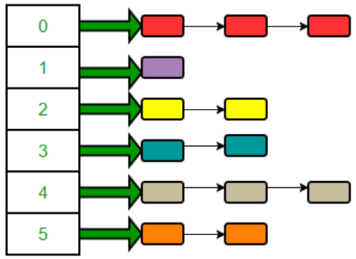
Control the Center	Doubled rooks on an open file are very strong
Develop pieces quickly	Bishops are better in open positions, knights are better in closed positions
Knights before bishops	The best way to deal with a flank attack, is with a counter attack in the center
Don't move the same piece twice in the opening	When 2 pawns can capture the same piece, capture towards the center
Don't bring your queen out too early	The king should be activated in the endgame
Castle before move 10	Rooks go behind passed pawns
Connect your rooks	2 connected passed pawns on the 6th rank will beat a rook
Rooks should go to open or half open files	Attack the base of a pawn chain
Knights on the rim are grim	Knights are usually the best piece to use to blockade a pawn
Try to avoid doubled pawns	If your position is cramped, trading pieces can help
Try to avoid isolated pawns	Trade your passive pieces for your opponent's active pieces
Try to avoid backward pawns	When ahead material, trade pieces, not pawns
Don't trade a bishop for a knight without a good reason	When behind material, trade pawns, not pieces
Avoid moving pawns in front of your castled king	Games with opposite colored bishops are dangerous in the middlegame, and drawish in the endgame
Don't open the center if your king is still there	Don't play "hope" chess
2 minor pieces are usually better than a rook and a pawn	When you see a good move, look for a better move
3 minor pieces are usually better than a queen	A really good chess player knows the right time to ignore a chess principle
Rooks are good on the 7th rank	

DS 2000: Programming with Data

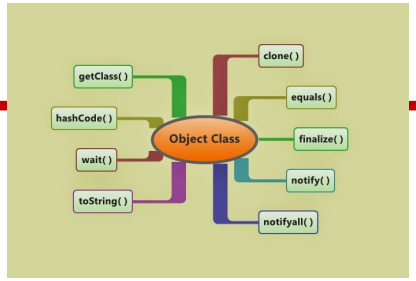
- *DS 2000* is the first course in Northeastern's *Programming with Data* sequence.
- DS 2000 is for DS majors, minors, and non-CS / non-DS majors. *No programming experience is assumed!*
- *DS 2000 is the one course to take if you are only going to take one programming course, or you want a broad introduction to Data Science.*

Some of the topics explored in DS2000:

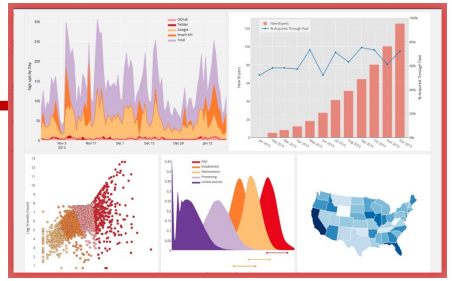
Reading and Processing Data



Data Structures and Algorithmic Thinking



Introduction to Object-Oriented Design

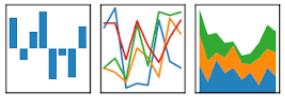


Creating Insightful Visualizations

python™

pandas

$y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$



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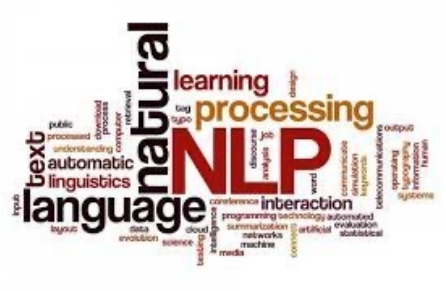
DS 2500: Intermediate Programming with Data

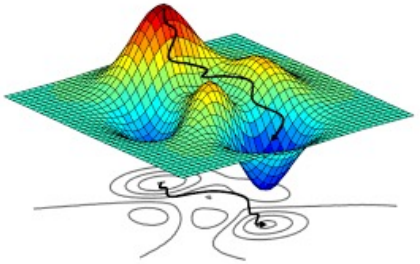
- *DS 2500* is the second course in Northeastern's *Programming with Data* sequence.
- DS 2500 is for DS majors, minors, and non-CS / non-DS majors who have taken DS 2000 or have equivalent programming experience.
- DS2500 is required for those wishing to eventually pursue more advanced data science courses such as DS3000 or DS3500.
- *DS 2500 is the course to take if you want to explore a broad range of data science topics using python.*

Some of the topics usually explored in DS2500:

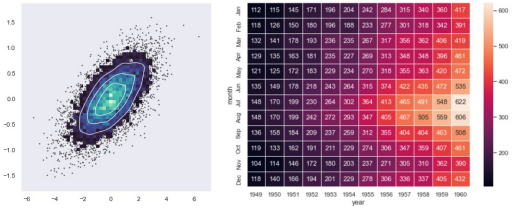


Natural Language Processing (NLP)

Graphs and Networks: Data structures and Analysis



Optimization and Machine Learning



Visualization Techniques

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$y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$

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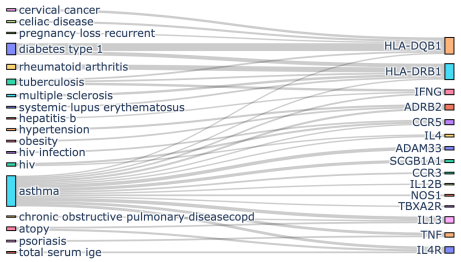
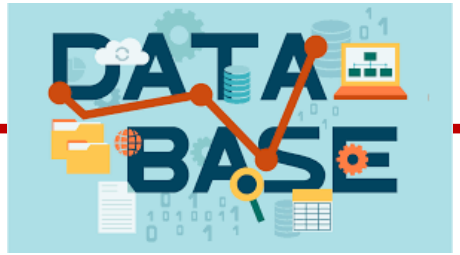
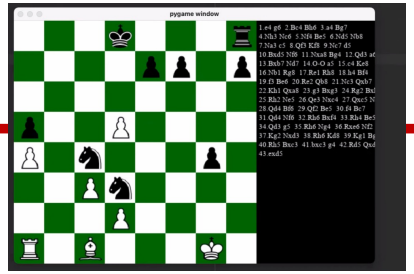
DS 3500: Advanced Programming with Data

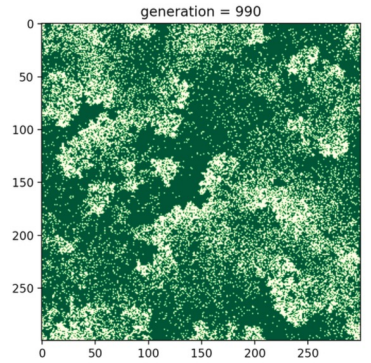
- *DS 3500* is the third and final course in Northeastern's *Programming with Data* sequence.
- *Requires DS2500: Intermediate Programming with Data*
- DS 3500 is for DS majors, minors, and non-CS / non-DS majors who have taken DS 2500 or have equivalent programming experience.
- *DS 3500 is the course to take if you want to become a professional software developer or data scientist.*

Some of the topics we will explore this Fall 2022:









Building Interactive Visualizations & Dashboards

Working with relational and non-relational databases

Object-oriented and functional paradigms.

Animation, Simulation, and Modeling

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$y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$

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DS3500 Topics

Tooling

- Managing environments
- Anaconda library management
- The *git* software control system
- The JetBrains PyCharm IDE

Techniques

- Exception handling
- Object-oriented design patterns
- Test-Driven Development
- Functional programming
- Decorator patterns / Profiling
- Type hints
- Extensibility

Modules

- Advanced visualization with plot.ly
- Modeling and simulation / Animation
- Risk analysis for business forecasting
- Building interactive dashboards
- Databases / Persistence
- Optimization and Intelligent Decision Support
- Evolutionary Computing
- Scientific computing / multi-core computing

- Working with streaming data
- Time-series analysis
- Data structures: Property graphs for Network Analysis
- Image processing
- Concurrency with *asyncio*
- Web-development / User-interfaces with *flask*
- Other?

DS3500 –Programming with Data

Setting up your Python development environment

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Three critical elements

Anaconda: A python distribution and environment manager (or "package manager") that comes pre-installed with a *base* environment containing hundreds of packages. (Mine currently has 278!)

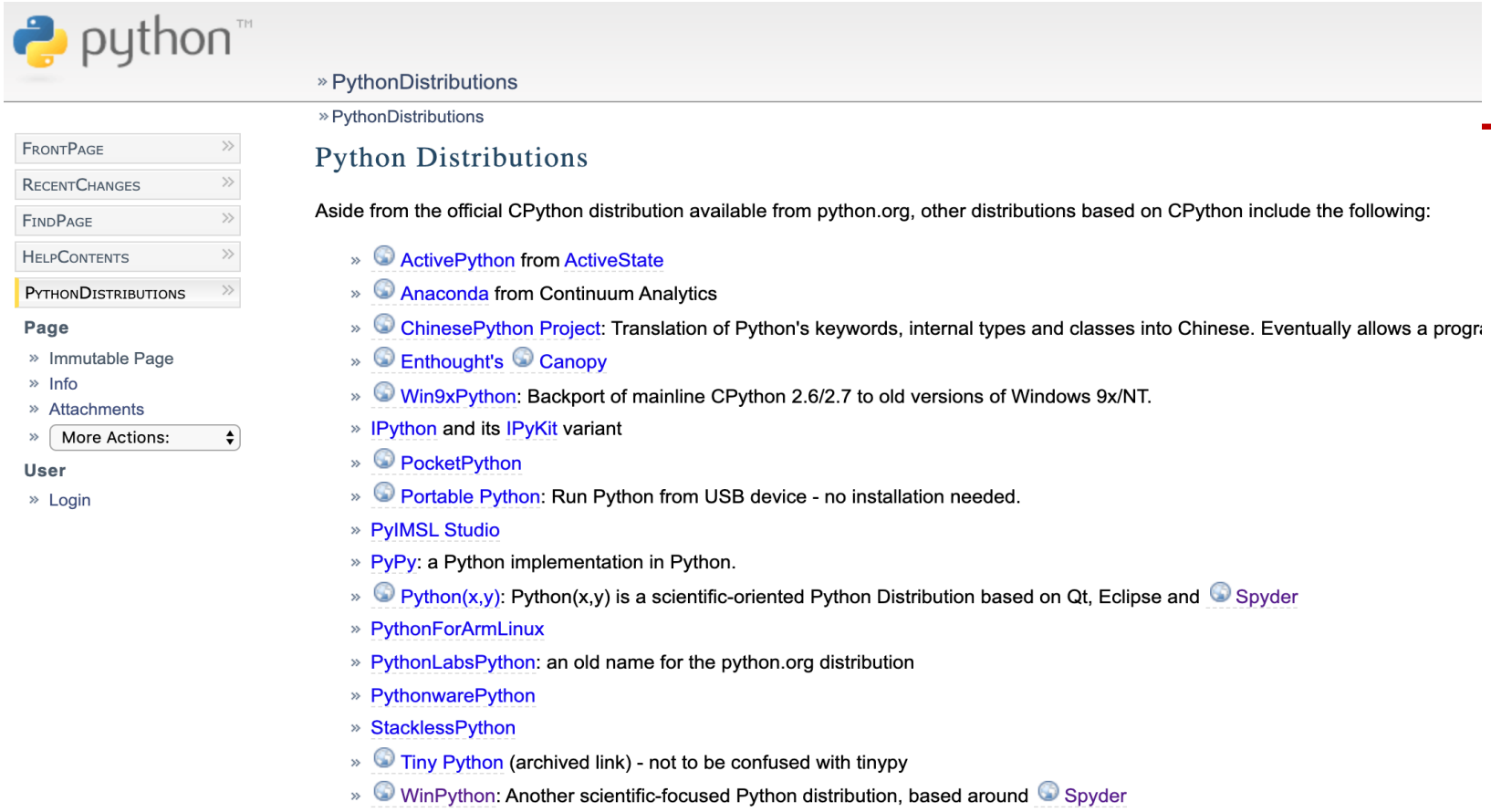
An **IDE** (Integrated Development Environment): For creating projects and writing, running, and testing code. We'll be mostly using **Jetbrains PyCharm** in class but I might sometimes revert to spyder or Jupyter Notebooks. PyCharm readily integrates with Anaconda environments.

GIT: A software control system – for working together on shared development projects. PyCharm integrates with GIT.

Python Distributions

A python *distribution* typically consists of:

- The python programming language
- Development tools
- Pre-installed python packages (libraries) that make python more powerful
- A package manager (allows you to customize your distribution by adding more libraries or updating existing libraries)



python™

» PythonDistributions

» PythonDistributions

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PythonDistributions

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» Info
» Attachments
» More Actions:

User

» Login

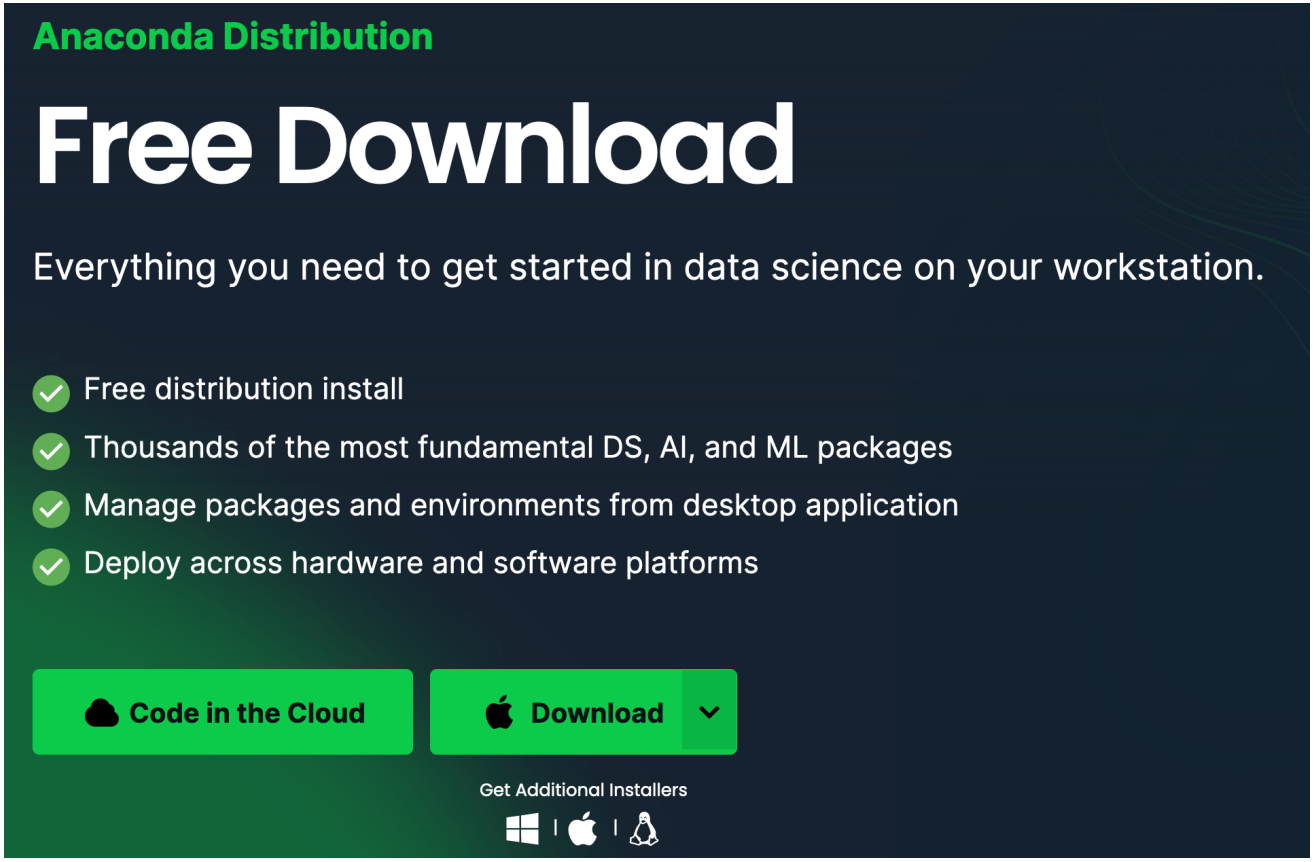
Python Distributions

Aside from the official CPython distribution available from python.org, other distributions based on CPython include the following:

» ActivePython from ActiveState
» Anaconda from Continuum Analytics
» ChinesePython Project: Translation of Python's keywords, internal types and classes into Chinese. Eventually allows a progr
» Enthought's Canopy
» Win9xPython: Backport of mainline CPython 2.6/2.7 to old versions of Windows 9x/NT.
» IPython and its IPyKit variant
» PocketPython
» Portable Python: Run Python from USB device - no installation needed.
» PyIMSL Studio
» PyPy: a Python implementation in Python.
» Python(x,y): Python(x,y) is a scientific-oriented Python Distribution based on Qt, Eclipse and Spyder
» PythonForArmLinux
» PythonLabsPython: an old name for the python.org distribution
» PythonwarePython
» StacklessPython
» Tiny Python (archived link) - not to be confused with tinypy
» WinPython: Another scientific-focused Python distribution, based around Spyder

There are other python distributions out there, but we'll use Anaconda.

www.anaconda.com/download



Anaconda installers

https://www.anaconda.com/download#downloads

(Skip Registration if you want.)

Installing Anaconda on a Mac

Anaconda3-2023.07-2-MacOSX-x86_64.pkg

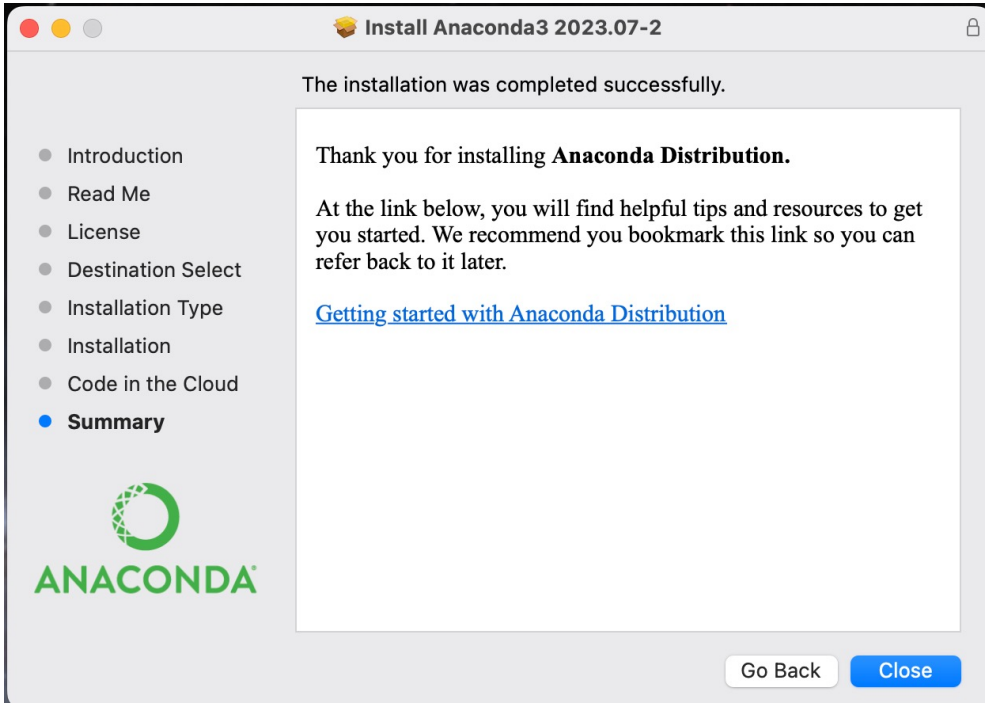
Completed — 611 MB

I chose /Users/rachlin/opt as my installation folder. The home directory for anaconda is then:

/Users/rachlin/opt/anaconda3

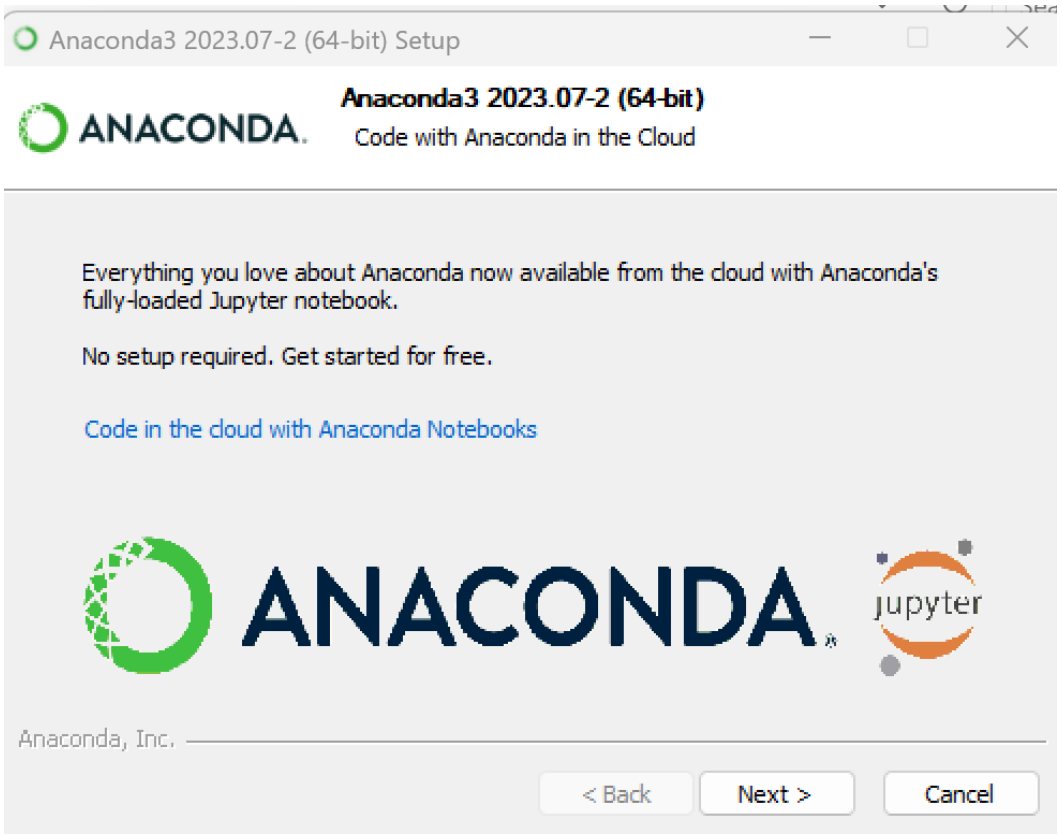
It installs Anaconda Navigator and tries to get you to set up a cloud account. I don't use it.

The "base" environment uses python 3.11.4

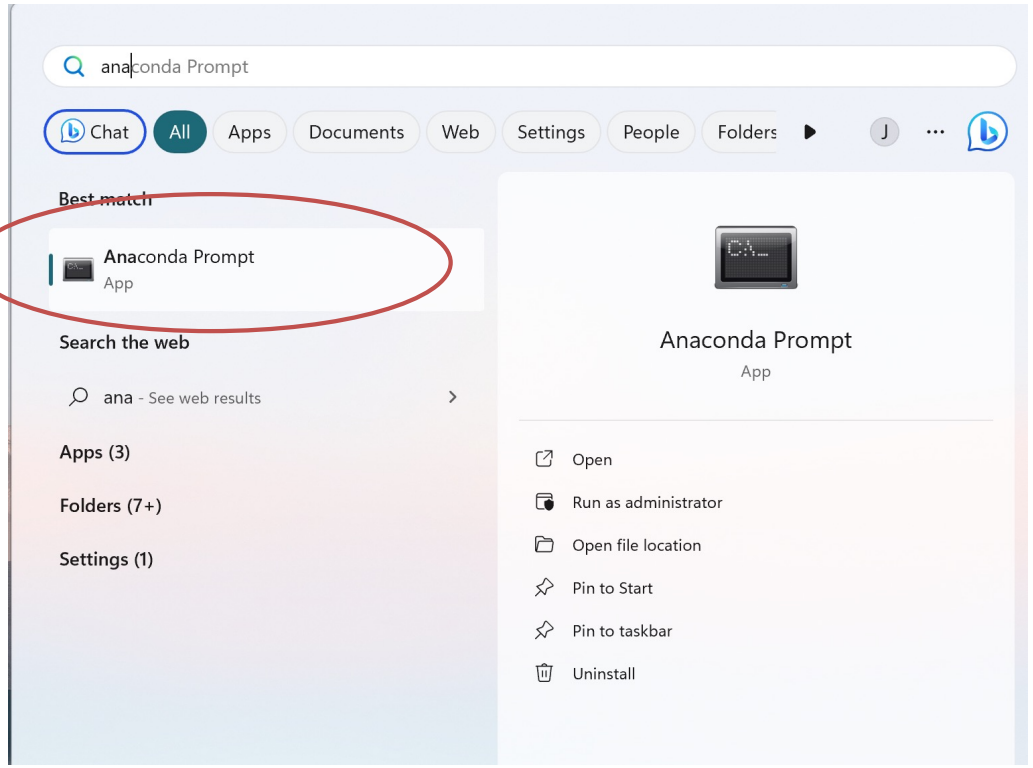


Anaconda on Windows

I just accepted defaults or any recommended buttons when installing on windows.



Running conda commands on Windows



To run “conda” commands on windows, use the Anaconda Prompt. (You might want to pin this application to your Task Bar.)

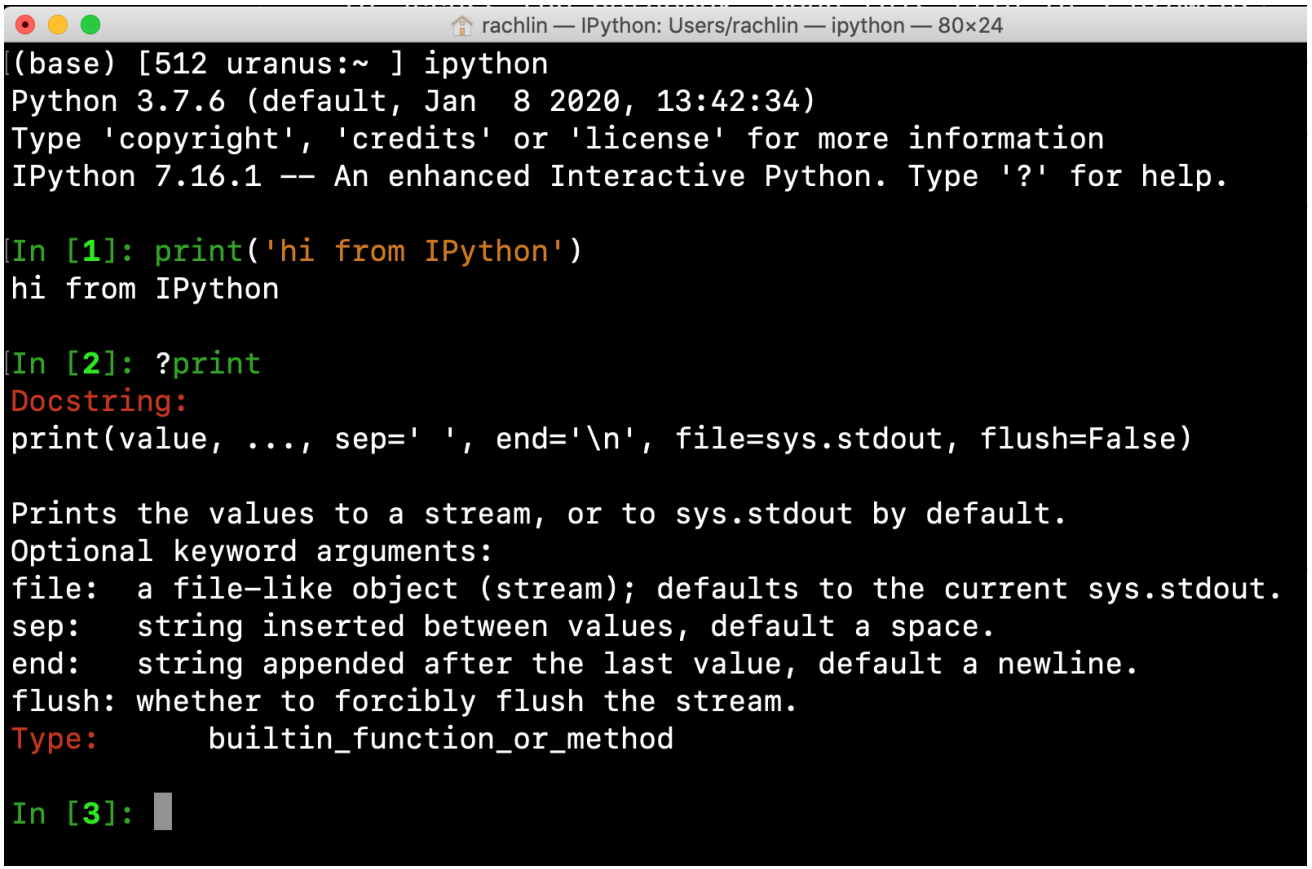
It basically opens a command terminal with the base anaconda environment activated.

conda info

Note that the base environment lives in the anaconda home directory. Other environments live in an **envs** subdirectory.

```
(base) [501 uranus:~ ] conda info

     active environment : base
    active env location : /Users/rachlin/opt/anaconda3
            shell level : 1
       user config file : /Users/rachlin/.condarc
 populated config files : /Users/rachlin/.condarc
          conda version : 23.7.2
    conda-build version : 3.26.0
         python version : 3.11.4.final.0
       virtual packages : __archspec=1=x86_64
                          __osx=10.16=0
                          __unix=0=0
       base environment : /Users/rachlin/opt/anaconda3  (writable)
      conda av data dir : /Users/rachlin/opt/anaconda3/etc/conda
  conda av metadata url : None
           channel URLs : https://repo.anaconda.com/pkgs/main/osx-64
                          https://repo.anaconda.com/pkgs/main/noarch
                          https://repo.anaconda.com/pkgs/r/osx-64
                          https://repo.anaconda.com/pkgs/r/noarch
          package cache : /Users/rachlin/opt/anaconda3/pkgs
                          /Users/rachlin/.conda/pkgs
       envs directories : /Users/rachlin/opt/anaconda3/envs
                          /Users/rachlin/.conda/envs
                platform : osx-64
              user-agent : conda/23.7.2 requests/2.31.0 CPython/3.11.4 Darwin/22.6.0 OSX/10.16
                 UID:GID : 501:20
              netrc file : None
            offline mode : False
```

IPython: An enhanced REPL for Python



Syntax highlighting
Code completion
Documentation

You'll want to install IPython in your **ds** environment. It's useful.

Create a “ds” environment

The base environment comes with almost 500 libraries, most of which you don’t need. Run the following commands to set up a **ds** environment with a few starting python libraries.

```
conda create --name ds python=3.11
conda activate ds
conda install matplotlib
conda install pandas
conda install ipython
```

Checking that I have two environments, and where they are located

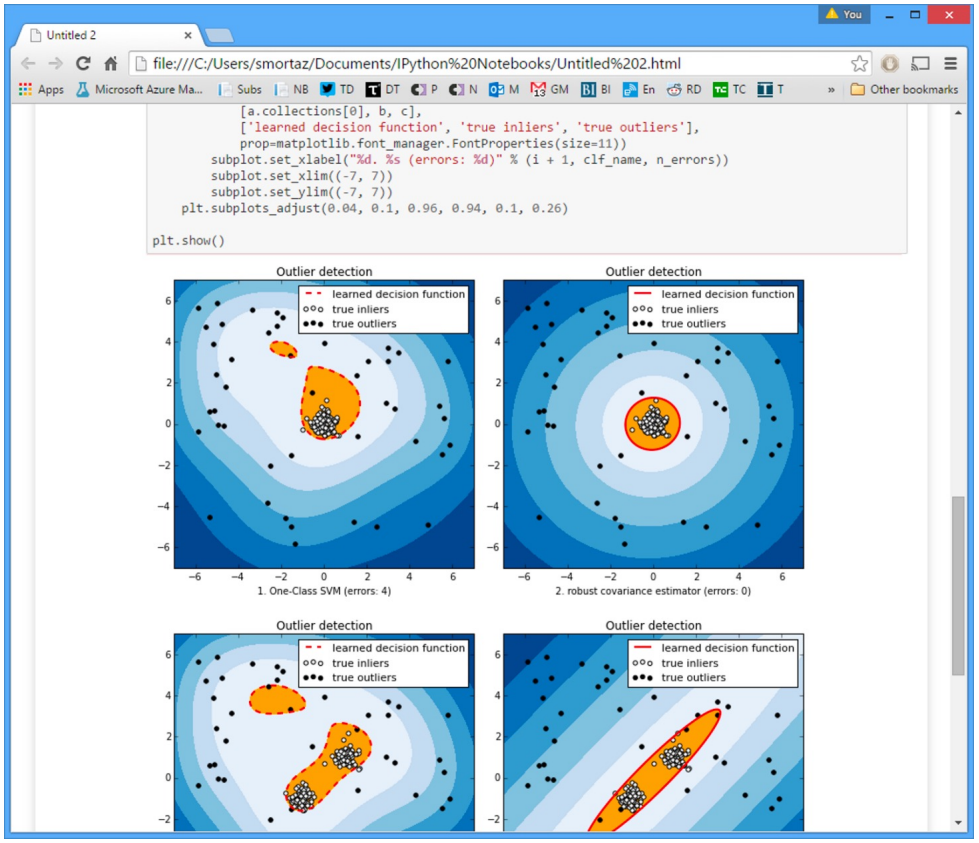
```
conda env list

# conda environments:
#
base                     /Users/rachlin/opt/anaconda3
ds                    *  /Users/rachlin/opt/anaconda3/envs/ds
```

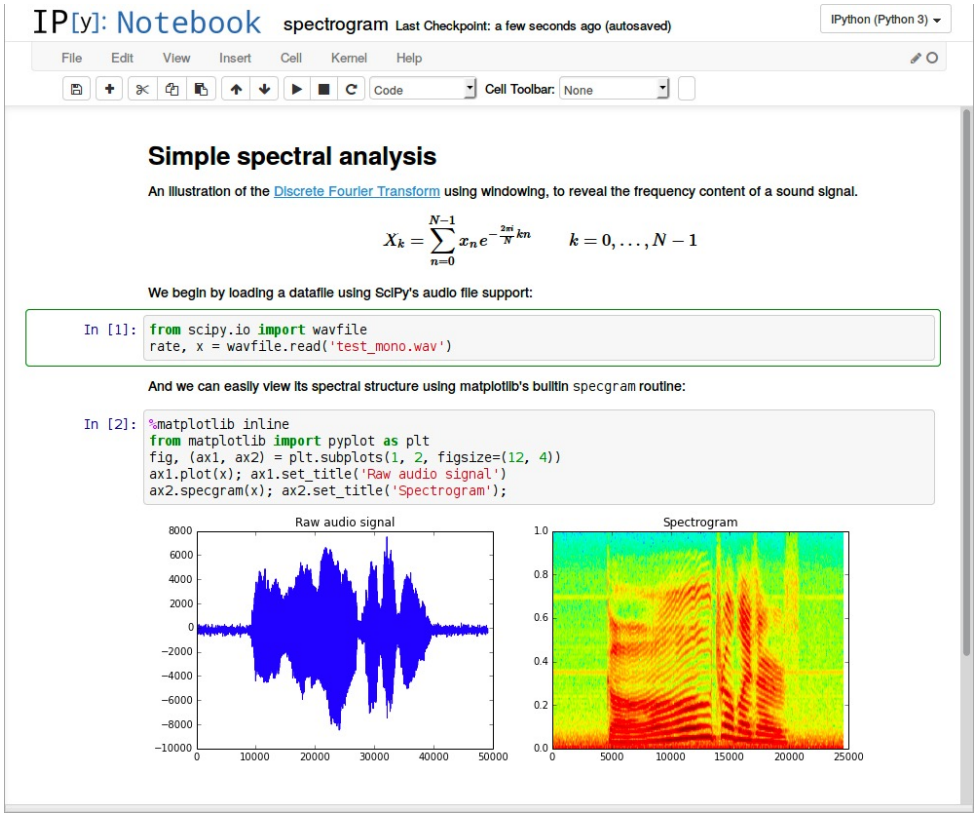
Environment locations on Windows

On windows, it is the same (but I have a different username).

```
(ds) C:\Users\johnr>conda env list
# conda environments:
#
base                     C:\Users\johnr\anaconda3
ds                    *  C:\Users\johnr\anaconda3\envs\ds
```

Jupyter Notebooks: Interactive Python for Data Science





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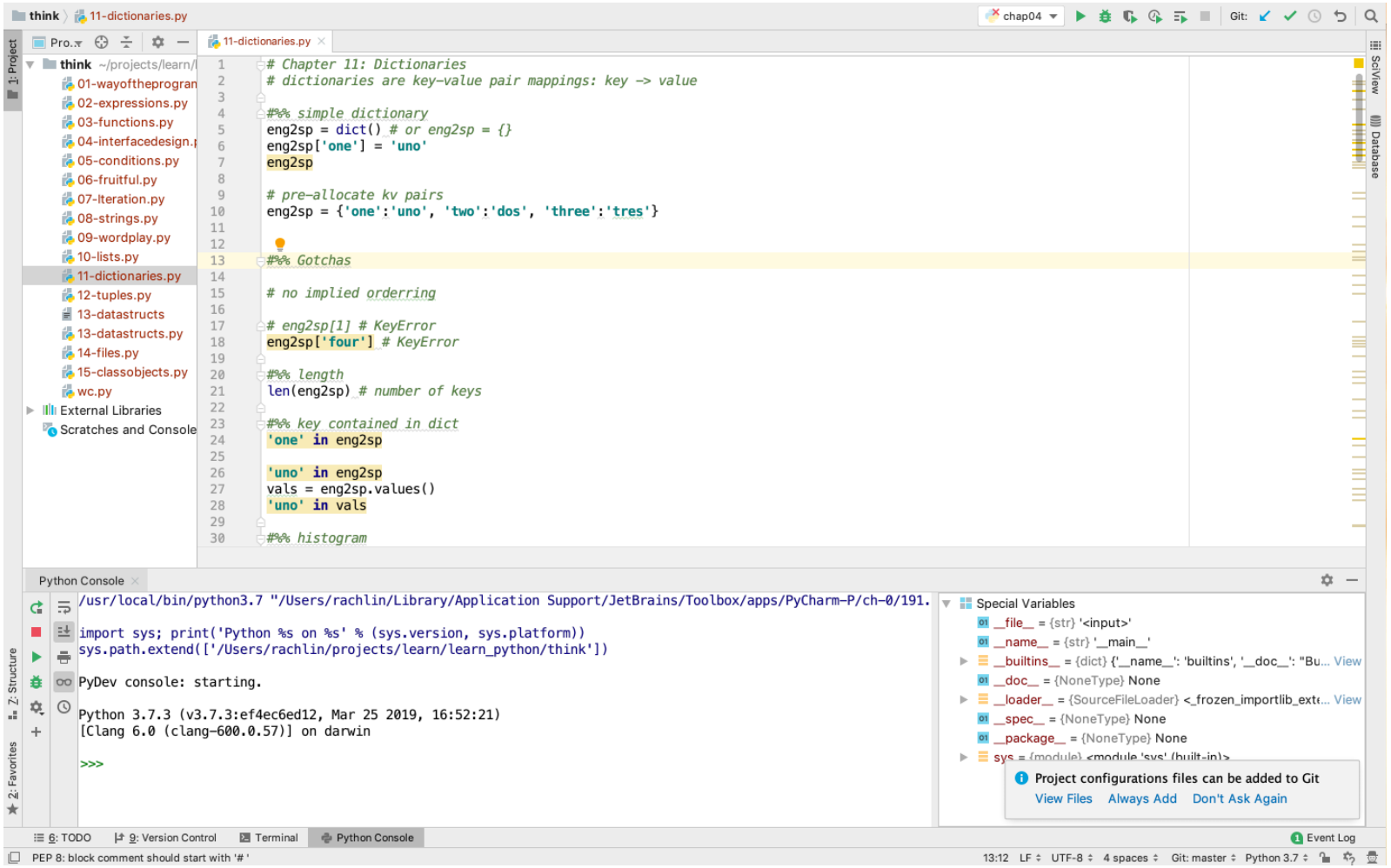
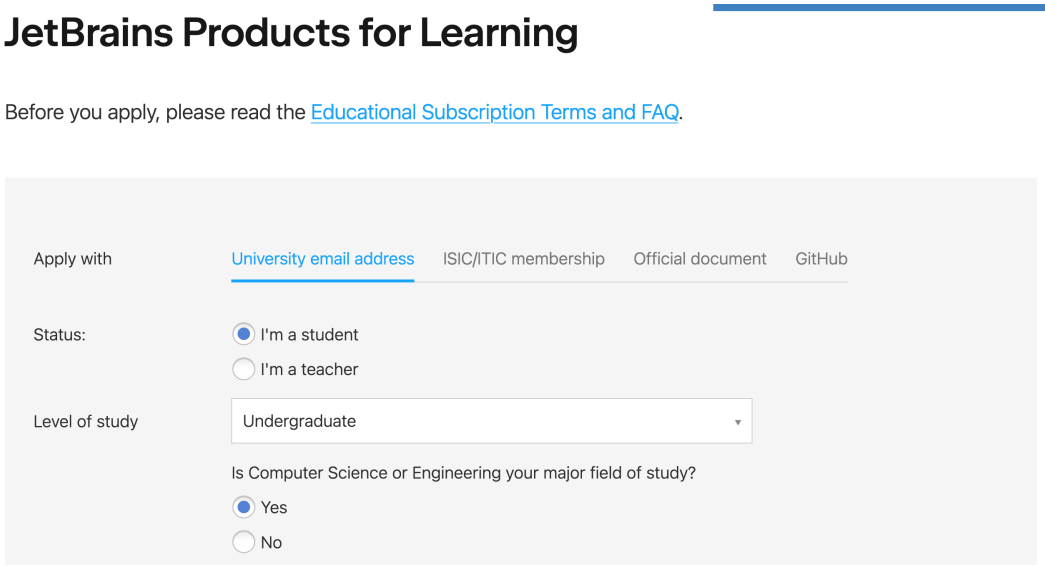
Jupyter is useful for data science but not for the types of programs we'll be writing in this class where we focus on code reuse by building *libraries.*

PyCharm (JetBrains): Recommended Python IDE



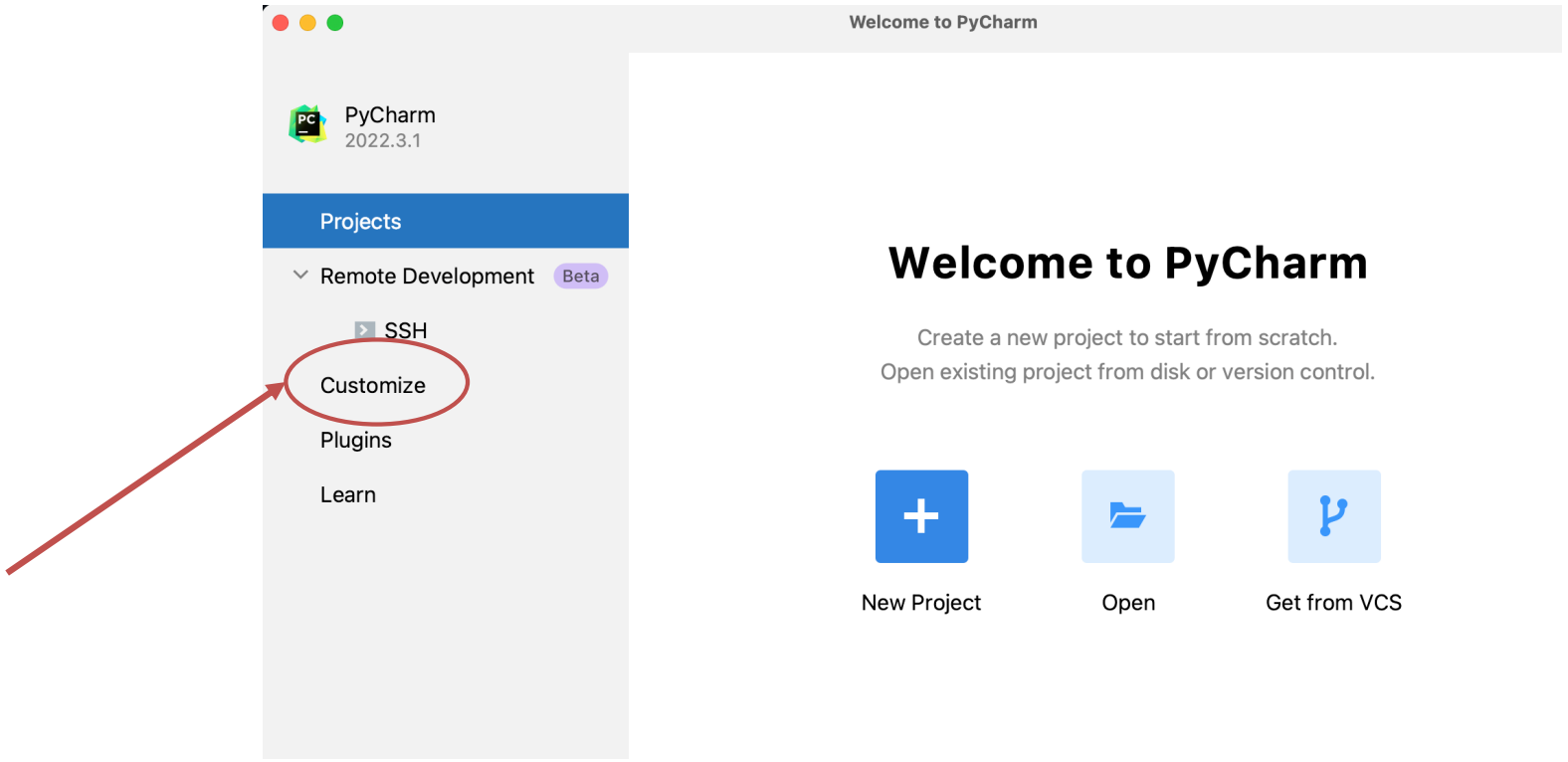
PyCharm: Community or Professional?

https://www.jetbrains.com/shop/eform/students

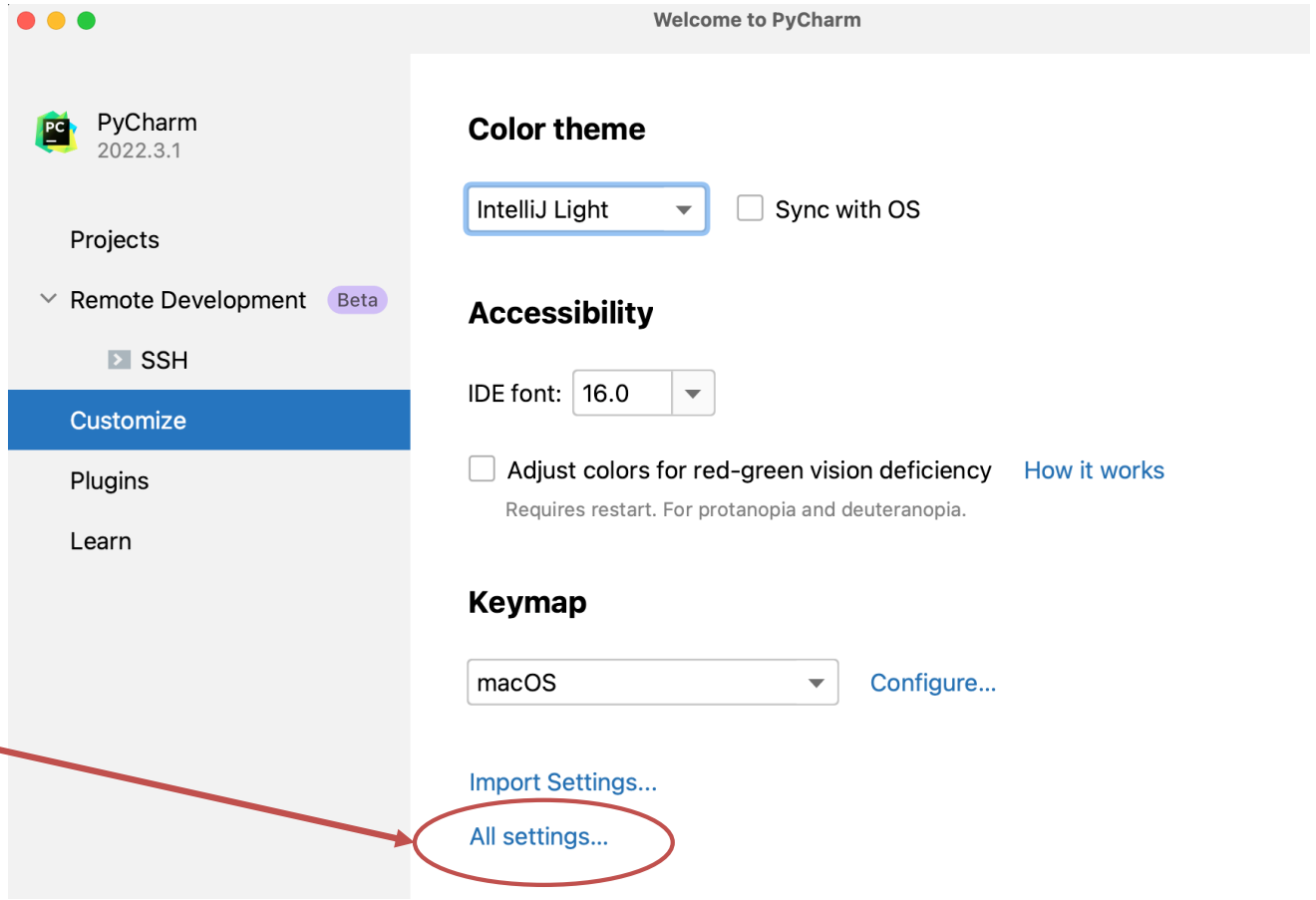


The community edition should be fine for this class, but you can get access to the professional edition and other JetBrains products for free by signing up for an Educational License (Free).

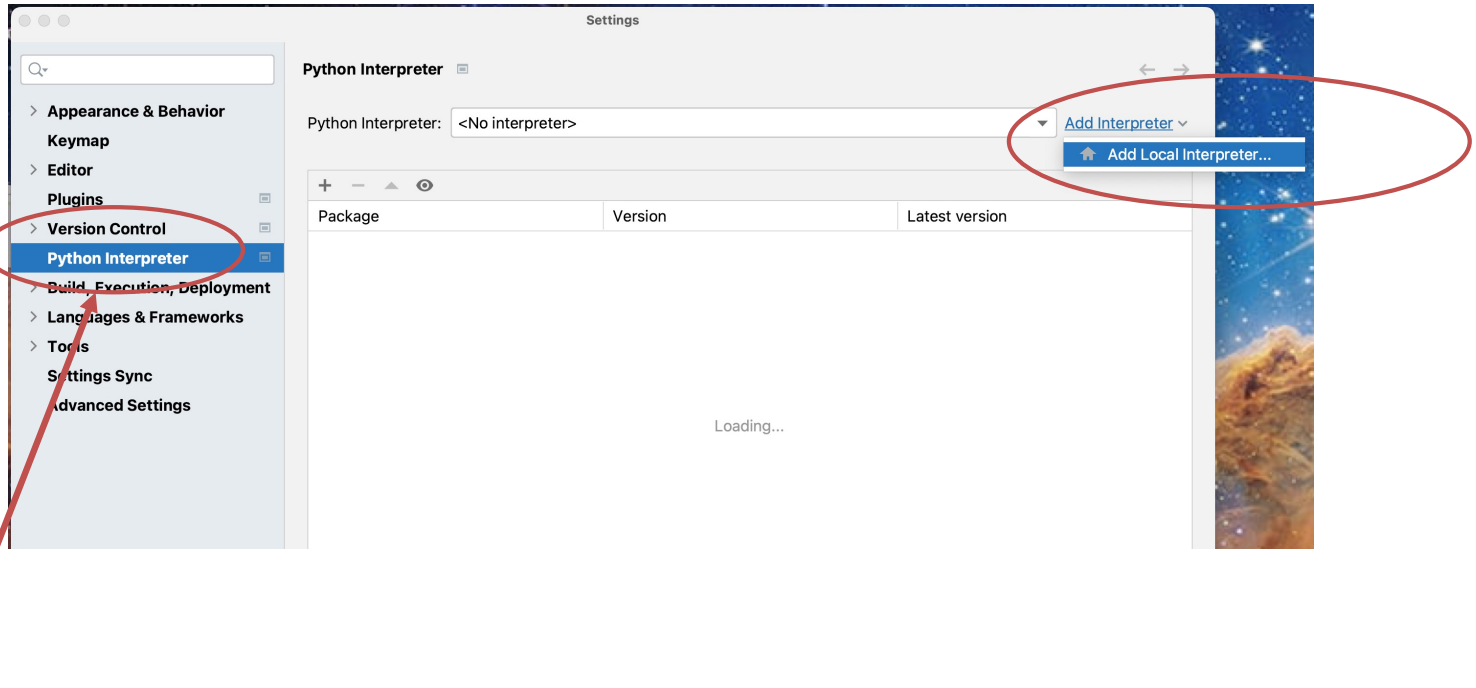
Connecting PyCharm project to an environment



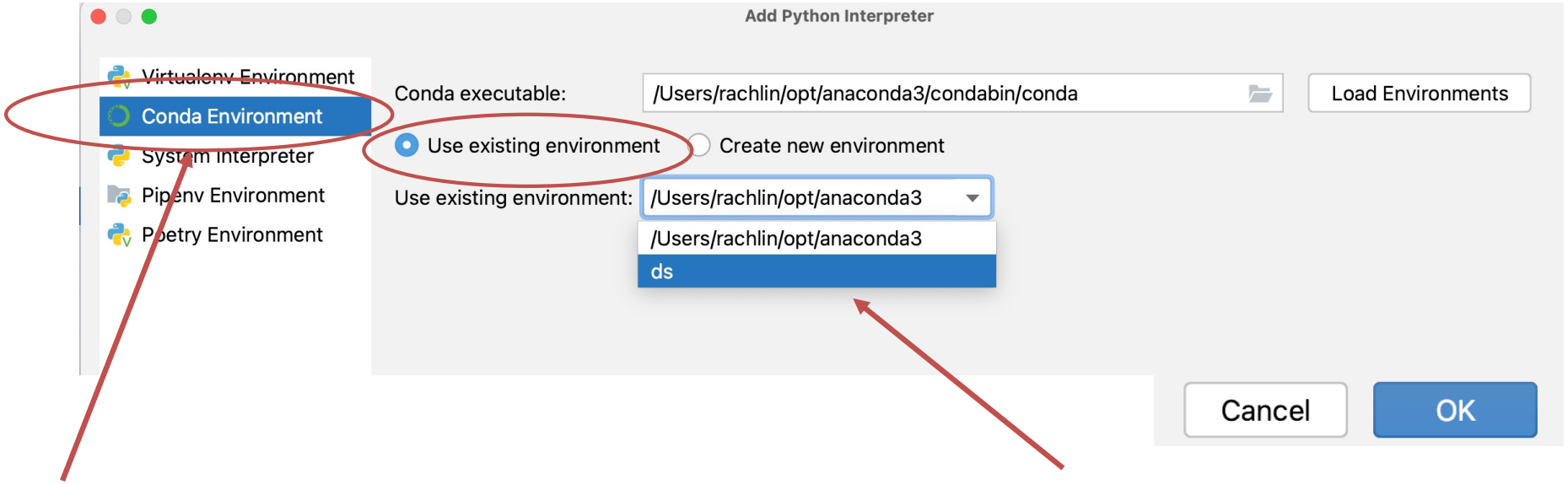
Connecting PyCharm project to an environment



Connecting PyCharm project to an environment

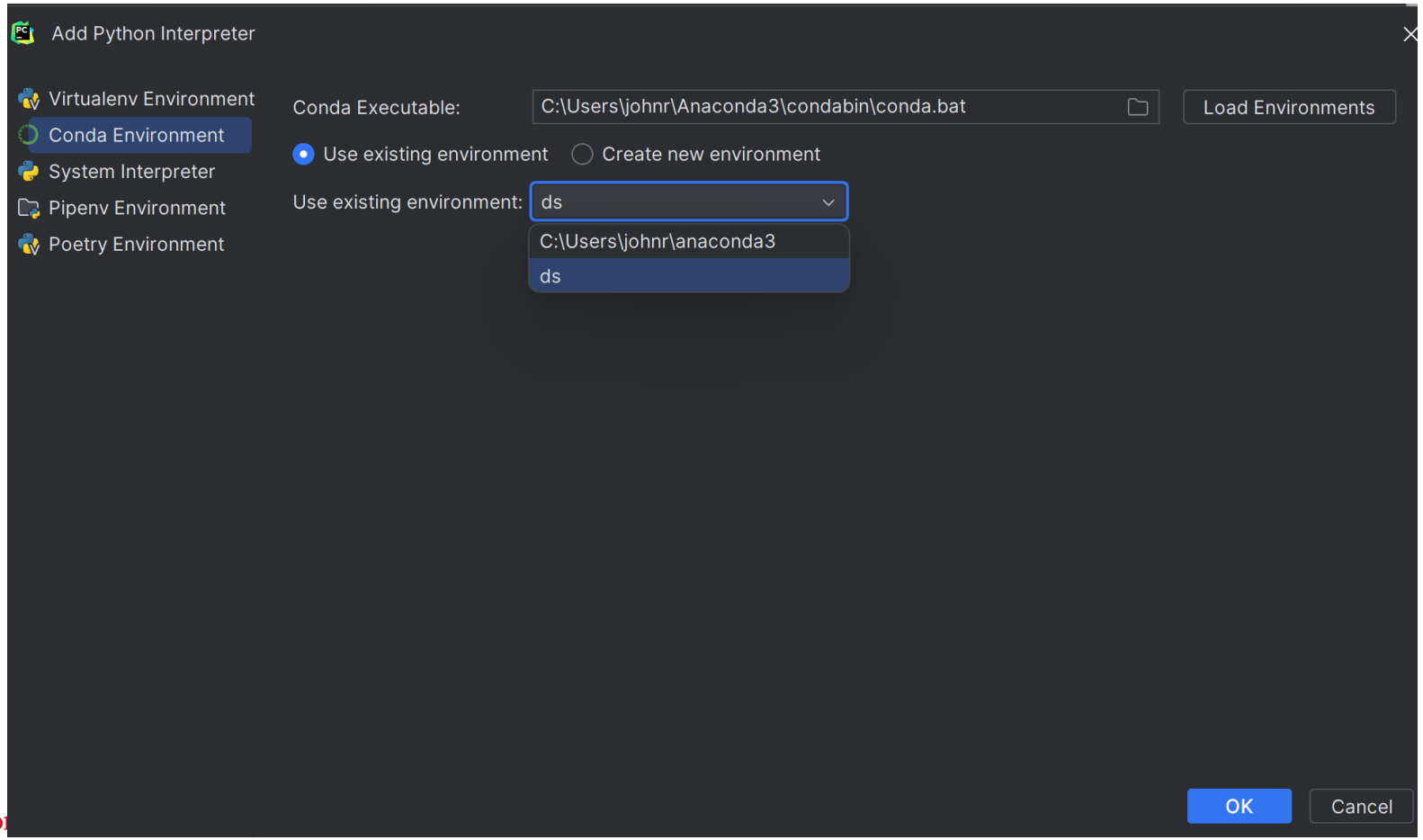


Connecting PyCharm project to an environment

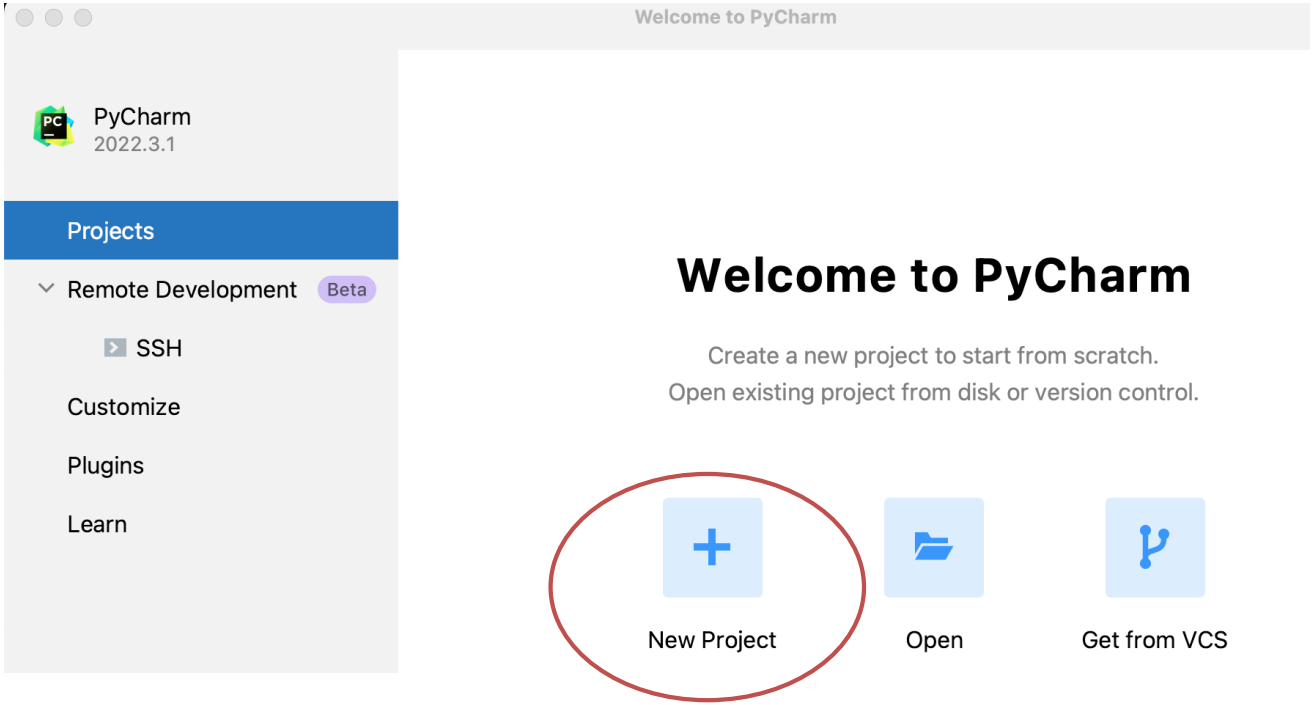


Select the “ds” environment you created and then press OK

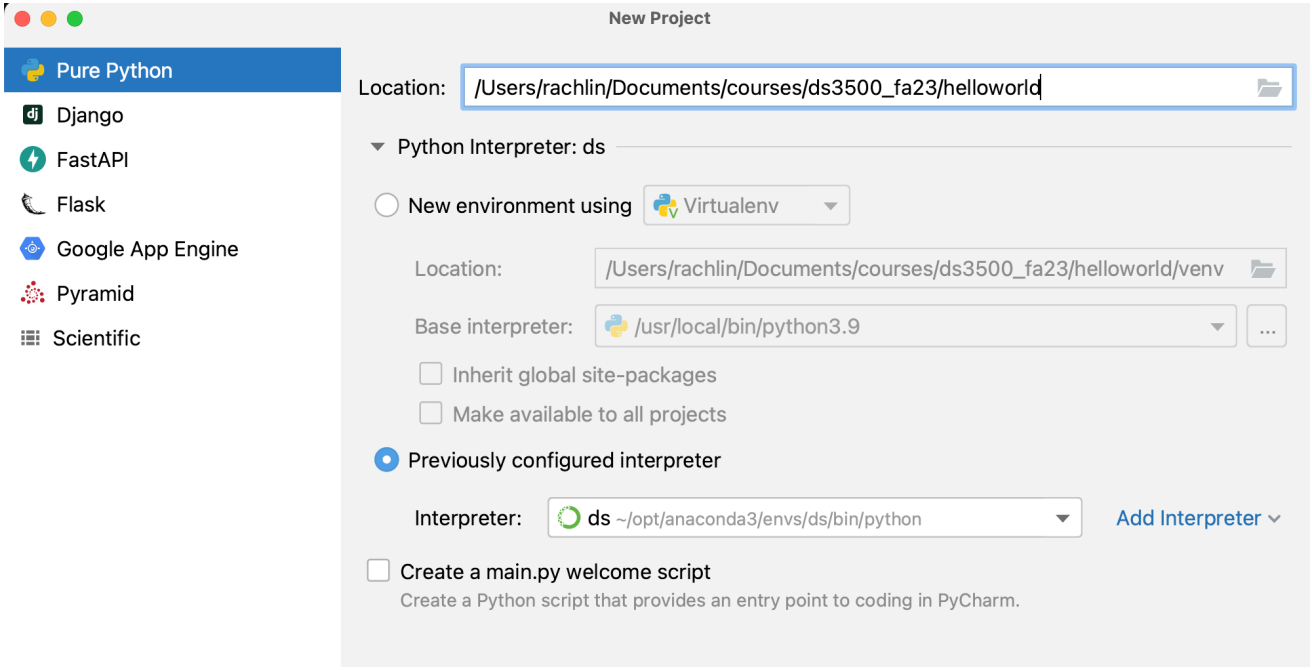
Very similar in Windows



Create your first project

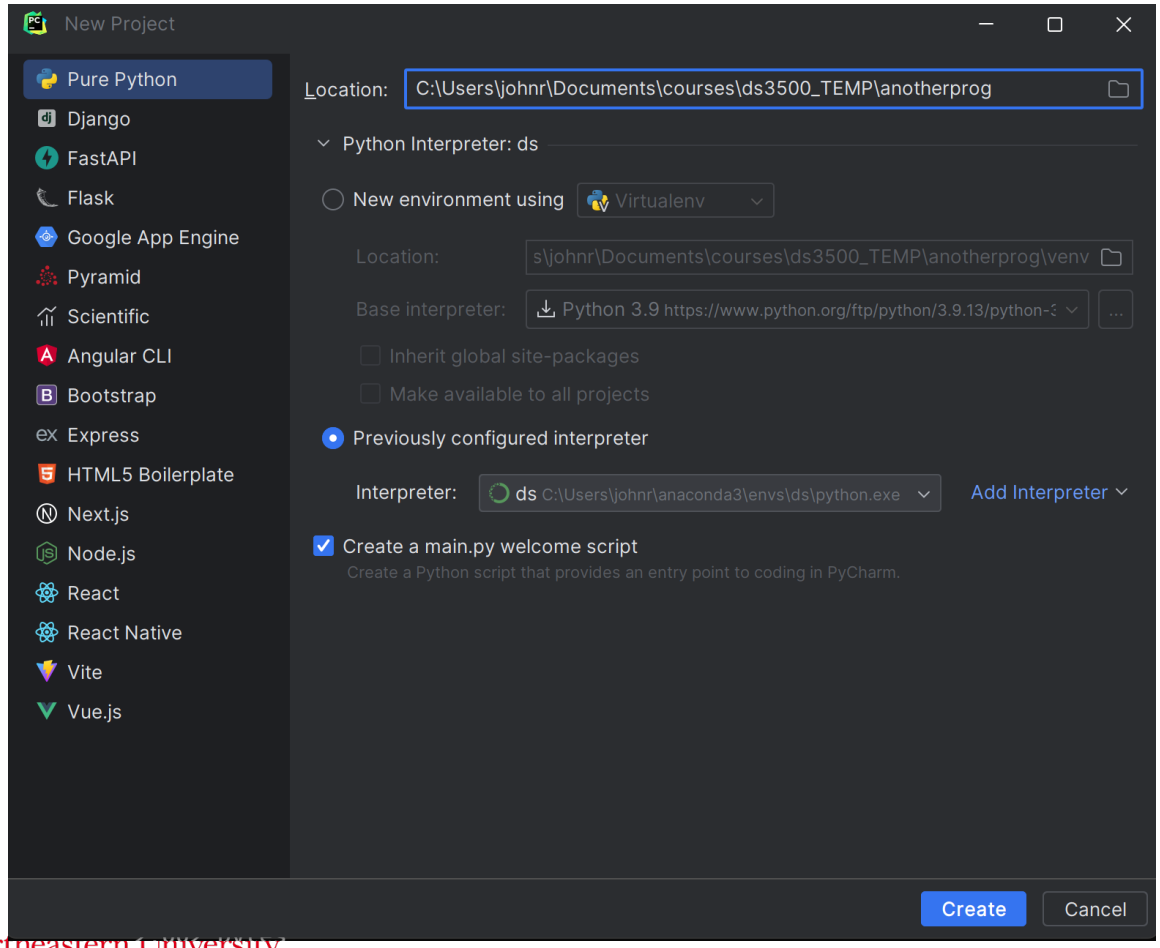


Create your first project



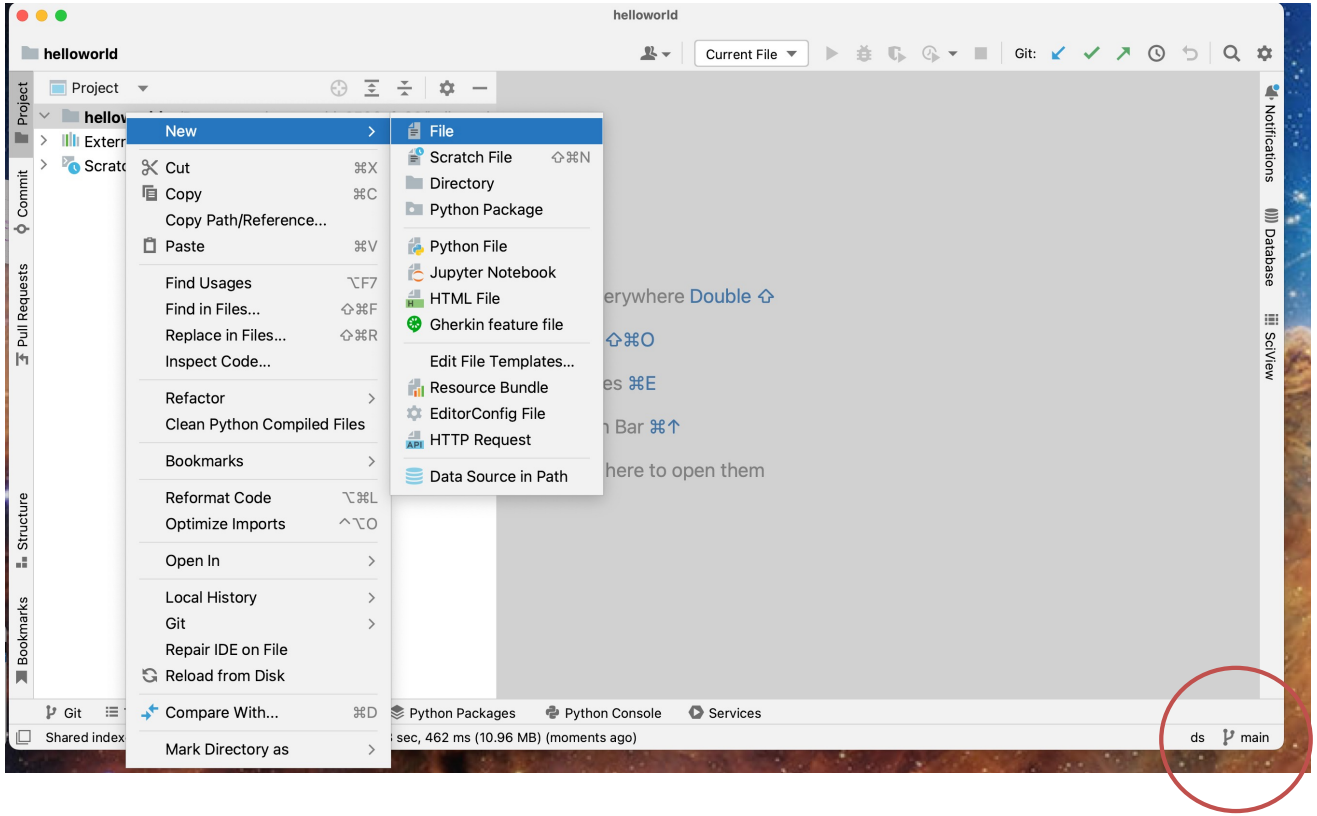
Here I'm creating a project folder in my local copy of the class repo (ds3500_fa23).
You would create YOUR projects and code outside the repo folders – perhaps in your OWN repo!

Windows: Creating a New Project (same)



I created this project
in a different repo / folder:
ds3500_TEMP

Creating our first python program



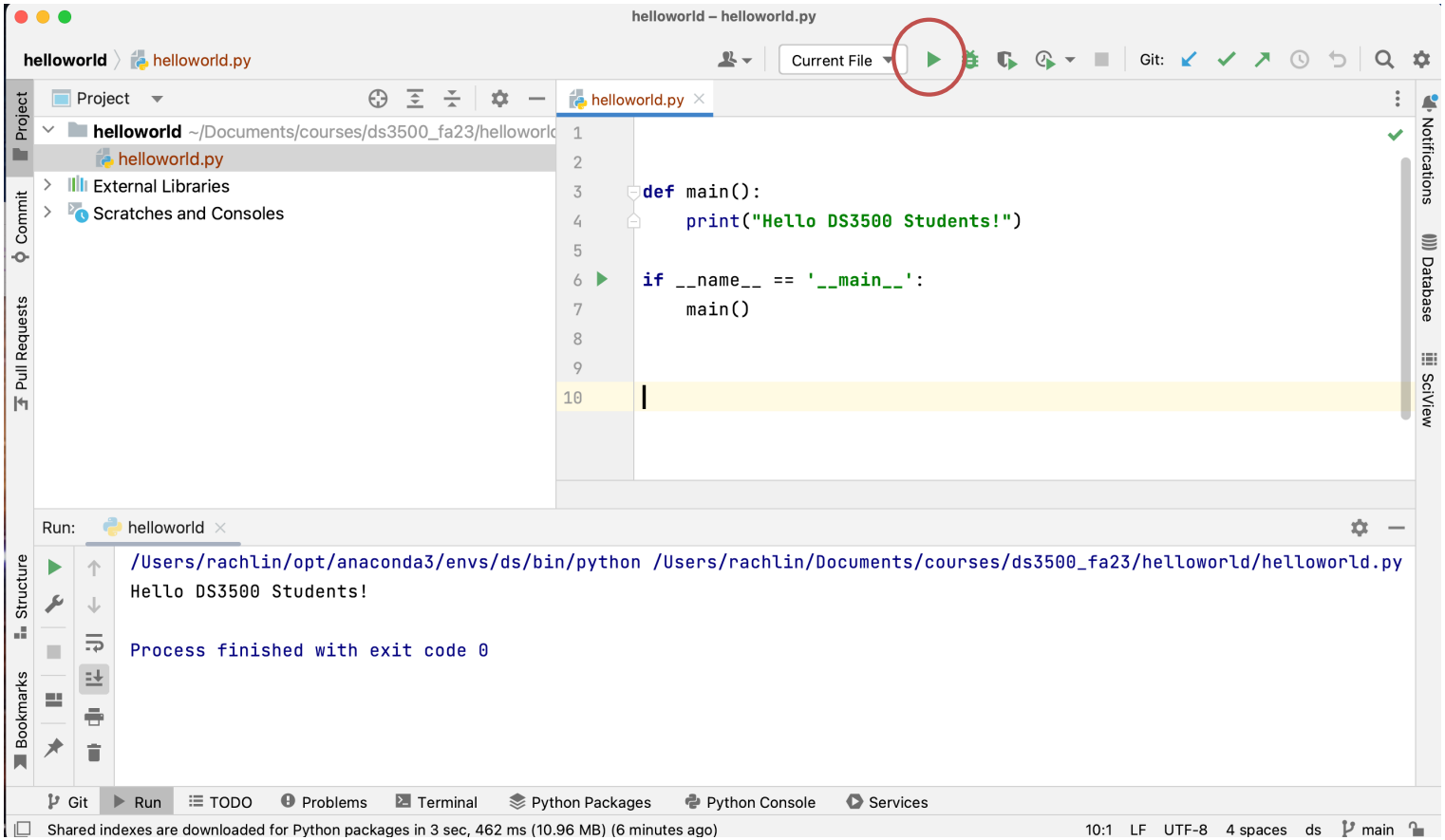
New File

helloworld.py

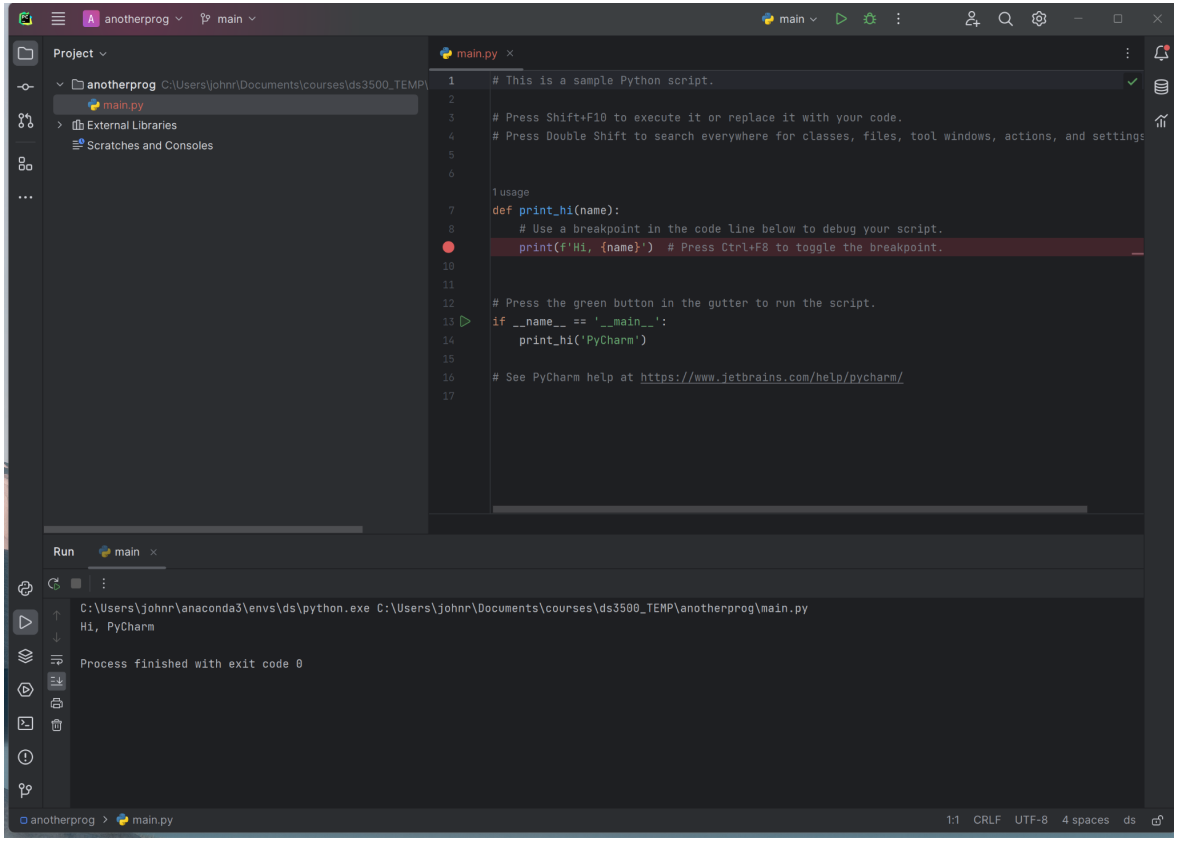
Right-clicking on the project name (**helloworld**) and adding a new file which will be called *helloworld.py.* Notice that “ds”, our active environment is listed in the status bar.

PyCharm knows this is a git repo and it is possible to manage your repo through PyCharm. I prefer to use the command line, so I will decline when PyCharm asks me about tracking newly created files.

Running our program



Windows Interface (dark theme)



You can choose different themes and syntax highlighting schemes.

Python Development Tools - Summary

Tool / Platform	Strengths and Weaknesses
IPython (RECOMMENDED)	Great for testing small snippets of Python and for learning Python syntax. Not intended for application development. IPython is an enhanced REPL for Python that comes packaged with the Anaconda distribution.
IDLE (NOT FOR ADVANCED)	Start coding today! Comes with Python distribution. Fine for small, single-file, stand-alone scripts or applications. Not recommended for more complex projects.
Atom text editor (OBSOLETE)	An extendible text-editor with many plugins for Python programming. See Prof. Rachlin's handout on recommended plugins.
Spyder (LIMITED)	A full-fledged IDE installed with the Anaconda distributions. Manage multiple files. Monitor variables. Run isolated blocks of code.
PyCharm (JetBrains) (RECOMMENDED)	Another popular IDE for python. Has more functionality than what you will need for this class. I won't be making use of PyCharm in this class, but you are welcome to explore its capabilities and use it for your homework.
Jupyter notebooks (PROTOTYPING ONLY)	A *notebook-style* development environment popular with data scientists. Integrate code, text, tables, visualizations in one file. Not suited for software *applications* requiring multiple python files.
Anaconda (REQUIRED)	A Python distribution that comes with Python, popular pre-installed libraries, and a variety of development tools including Spyder, Ipython, and Jupyter notebooks. The Anaconda Navigator is a jumping-off point for applications, learning resources, and community forums. **Recommended.**

Installing Git on a Mac

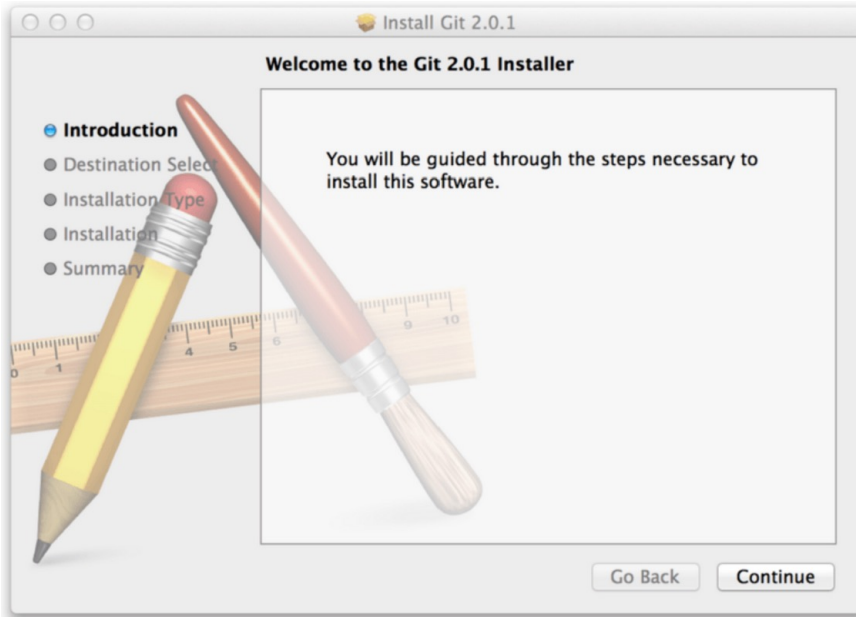
The Git Pro books has instructions: https://git-scm.com/book/en/v2/Getting-Started-Installing-Git

There are several ways to install Git on macOS. The easiest is probably to install the Xcode Command Line Tools. On Mavericks (10.9) or above you can do this simply by trying to run `git` from the Terminal the very first time.

```
$ git --version
```

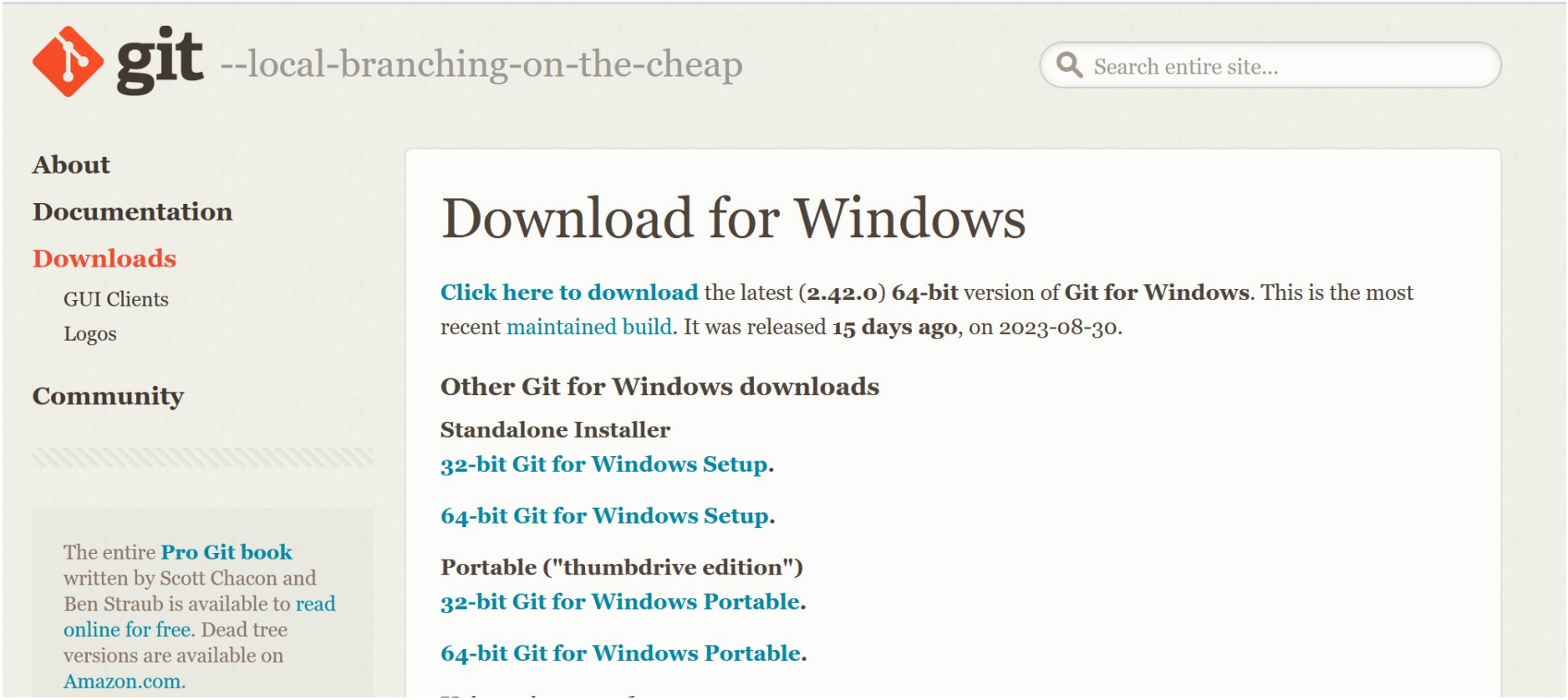
If you don't have it installed already, it will prompt you to install it.

If you want a more up to date version, you can also install it via a binary installer. A macOS Git installer is maintained and available for download at the Git website, at https://git-scm.com/download/mac.



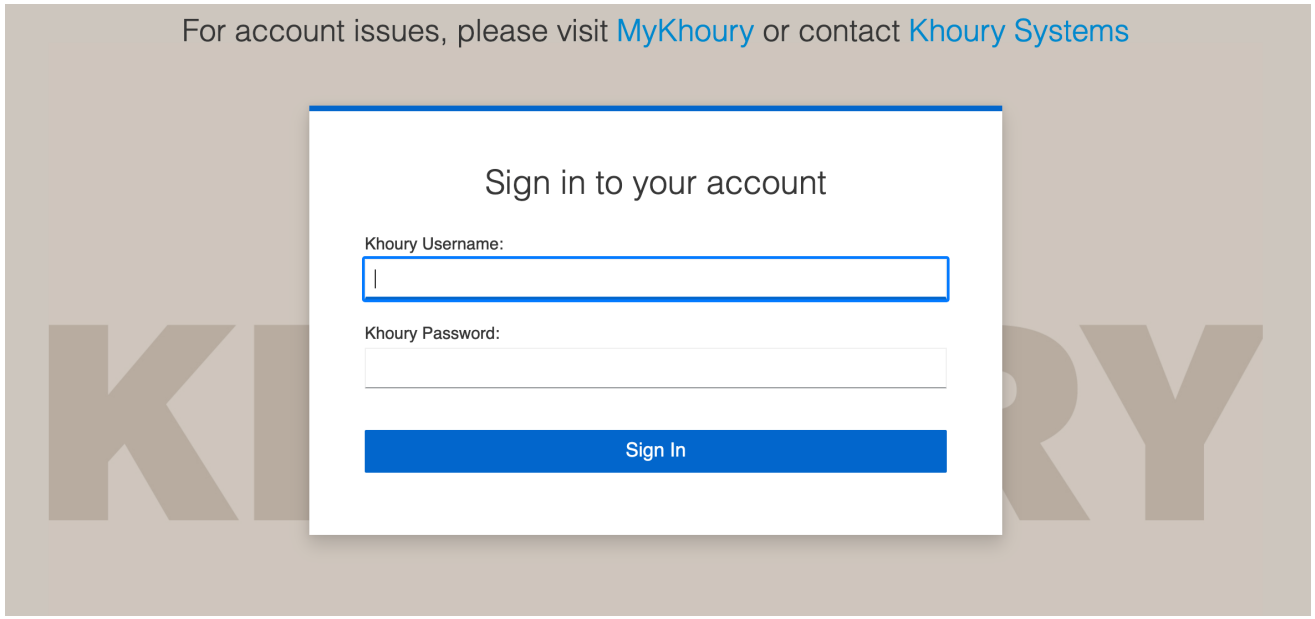
Installing Git on windows.

The Git Pro books has instructions: https://git-scm.com/book/en/v2/Getting-Started-Installing-Git



The Khoury Enterprise GIT Server

https://github.khoury.northeastern.edu/



Post-git Installation Commands

Your Identity

The first thing you should do when you install Git is to set your user name and email address. This is important because every Git commit uses this information, and it's immutably baked into the commits you start creating:

```
$ git config --global user.name "John Doe"
$ git config --global user.email johndoe@example.com
```

Again, you need to do this only once if you pass the `--global` option, because then Git will always use that information for anything you do on that system. If you want to override this with a different name or email address for specific projects, you can run the command without the `--global` option when you're in that project.

Many of the GUI tools will help you do this when you first run them.

Post-git Installation Commands

Your Editor

Now that your identity is set up, you can configure the default text editor that will be used when Git needs you to type in a message. If not configured, Git uses your system's default editor.

If you want to use a different text editor, such as Emacs, you can do the following:

```
$ git config --global core.editor emacs
```

On a Windows system, if you want to use a different text editor, you must specify the full path to its executable file. This can be different depending on how your editor is packaged.

In the case of Notepad++, a popular programming editor, you are likely to want to use the 32-bit version, since at the time of writing the 64-bit version doesn't support all plug-ins. If you are on a 32-bit Windows system, or you have a 64-bit editor on a 64-bit system, you'll type something like this:

```
$ git config --global core.editor "'C:/Program Files/Notepad++/notepad++.exe' -multiInst -notabbar -nosession -noPlugin"
```

GIT Repository List

Why is my face so big?

rachlin
rachlin

Associate Teaching Professor Khoury
College of Computer Sciences
Northeastern University

Edit profile

Overview | Repositories | Projects | Stars

Find a repository... | Type | Language | Sort | New

ds3500_fa23 Public
Official Class Repo for DS3500 (Fall 2023)
13 Updated 6 hours ago
Star

ds3500_sp23 Private
Course Repository for DS3500 (Sp23)
Jupyter Notebook Updated on Apr 7
Star

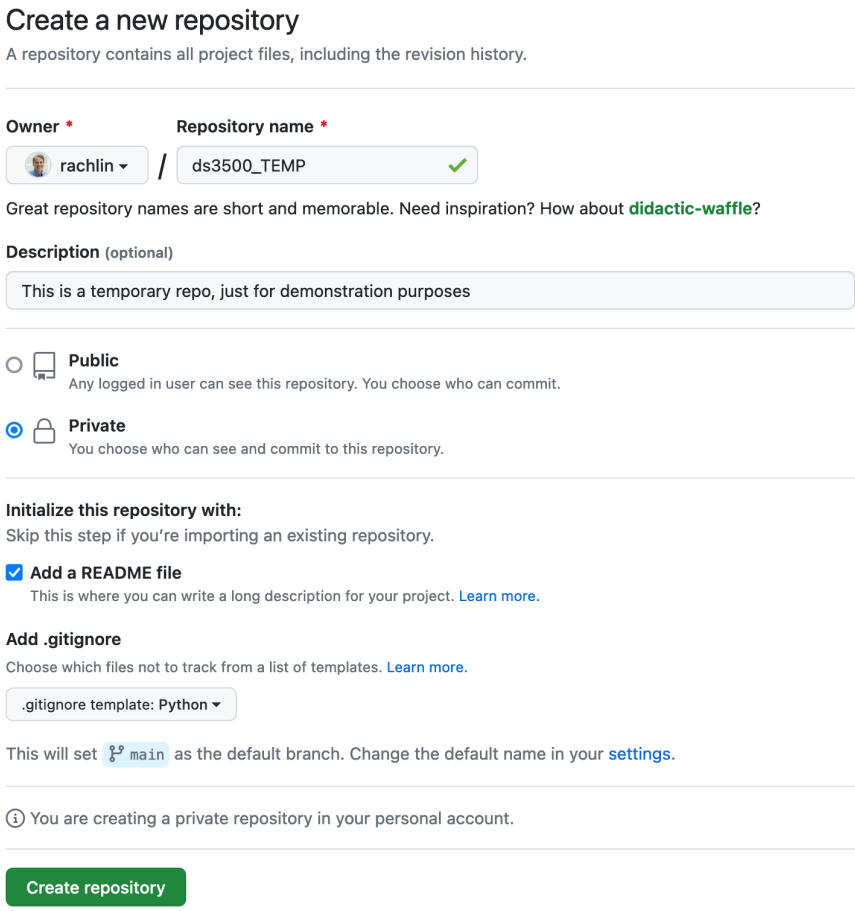
web Private
Khoury Website
HTML Updated on Feb 7
Star

Creating a new repository

Here I'm creating a PRIVATE repo called ds3500_TEMP.

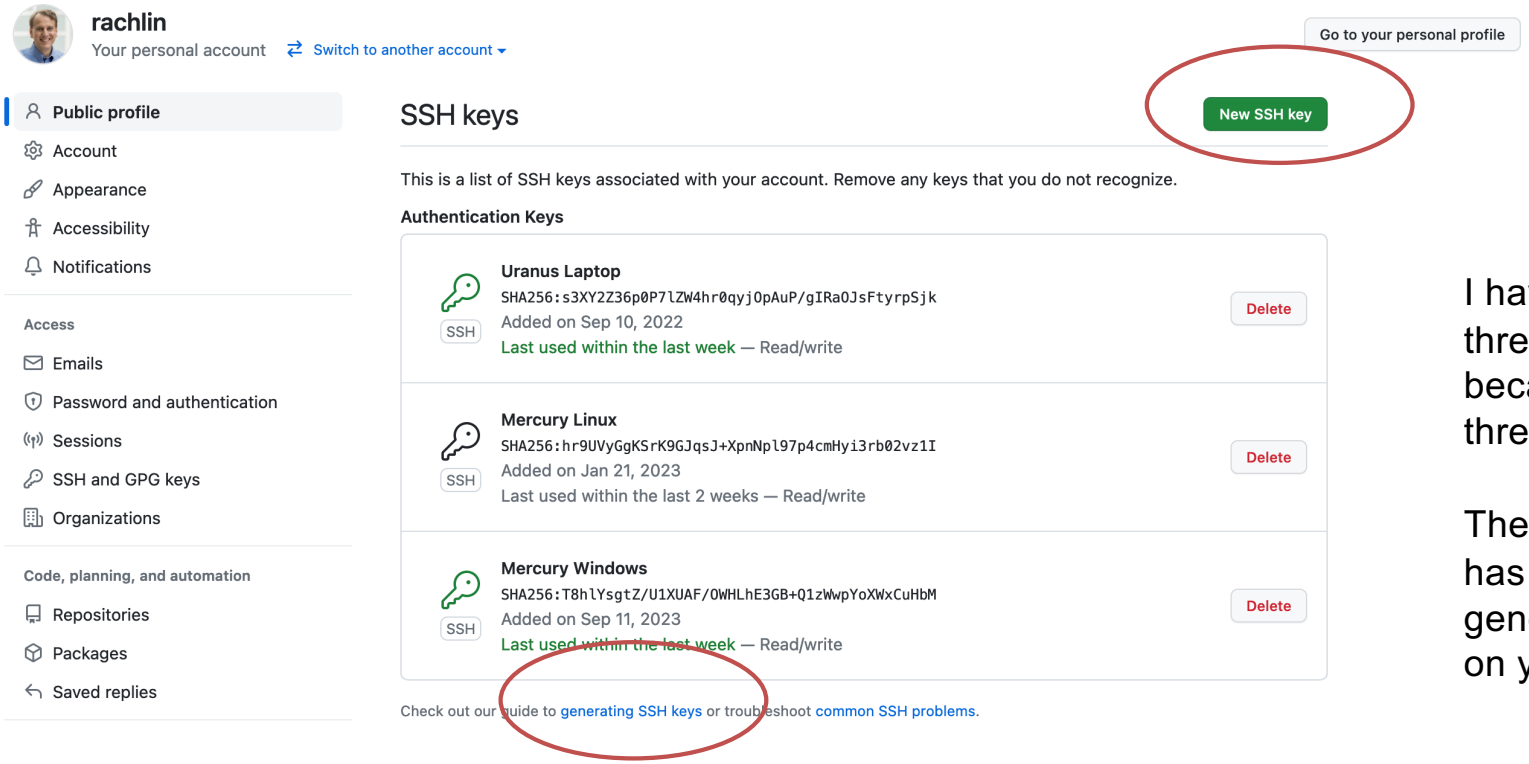
I'll have a README file.

Setting the .gitignore template to Python means that when we check for new files to add to the repo, git will ignore certain files and folders related to working with python projects or with particular IDEs but that are not part of the code base.



SSH Keys

Before I can clone my repo or run other git commands, I have to register my laptop with the Khoury Enterprise Git Server. **Go to Settings…. SSH and GPG Keys.**



I have registered three SSH keys because I use three machines.

The link at the bottom has instructions for generating SSH keys on your machine.

Generating SSH Keys

https://docs.github.com/en/enterprise-server@3.9/authentication/connecting-to-github-with-ssh/generating-a-new-ssh-key-and-adding-it-to-the-ssh-agent

Generating a new SSH key

You can generate a new SSH key on your local machine. After you generate the key, you can add the public key to your account on your GitHub Enterprise Server instance to enable authentication for Git operations over SSH.

If you are a site administrator for your GitHub Enterprise Server instance, you can use the same key to grant yourself administrative SSH access to the instance. For more information, see "Accessing the administrative shell (SSH)."

1. Open Terminal.
2. Paste the text below, substituting in your GitHub Enterprise Server email address.

```
ssh-keygen -t ed25519 -C "your_email@example.com"
```

Use your northeastern.edu email address.

Generating SSH Keys

https://docs.github.com/en/enterprise-server@3.9/authentication/connecting-to-github-with-ssh/generating-a-new-ssh-key-and-adding-it-to-the-ssh-agent

3. When you're prompted to "Enter a file in which to save the key", you can press **Enter** to accept the default file location. Please note that if you created SSH keys previously, ssh-keygen may ask you to rewrite another key, in which case we recommend creating a custom-named SSH key. To do so, type the default file location and replace id_ssh_keyname with your custom key name.

```
> Enter a file in which to save the key (/Users/YOU/.ssh/id_ALGORITHM): [Press enter]
```

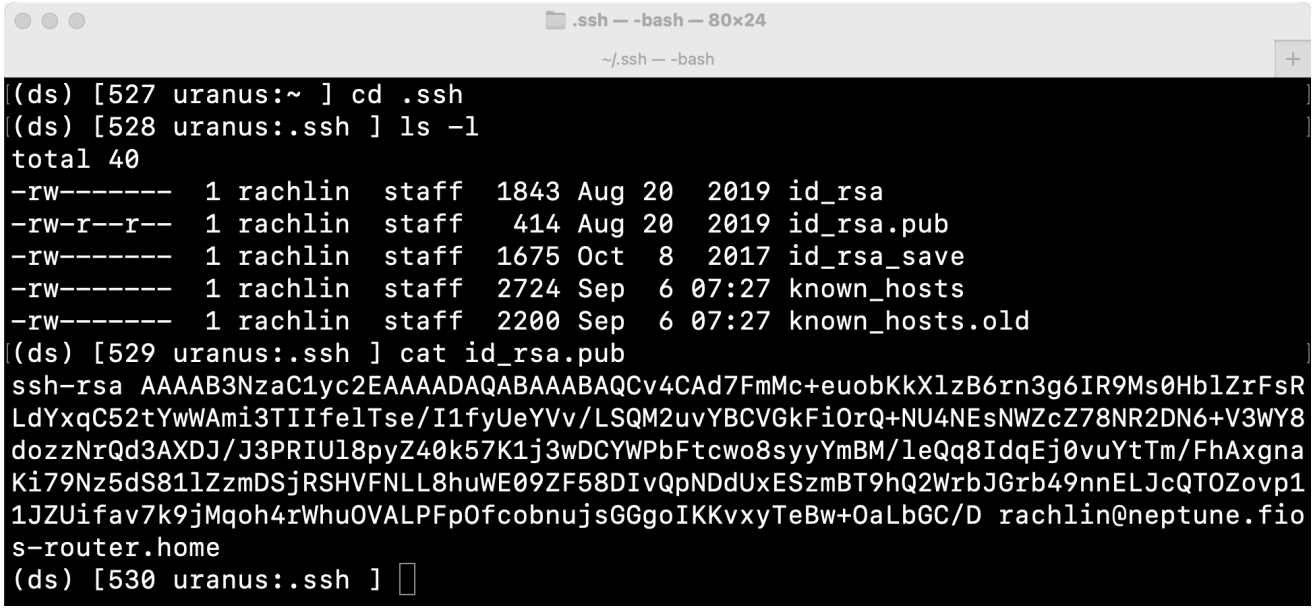
4. At the prompt, type a secure passphrase. For more information, see "Working with SSH key passphrases."

```
> Enter passphrase (empty for no passphrase): [Type a passphrase]
> Enter same passphrase again: [Type passphrase again]
```

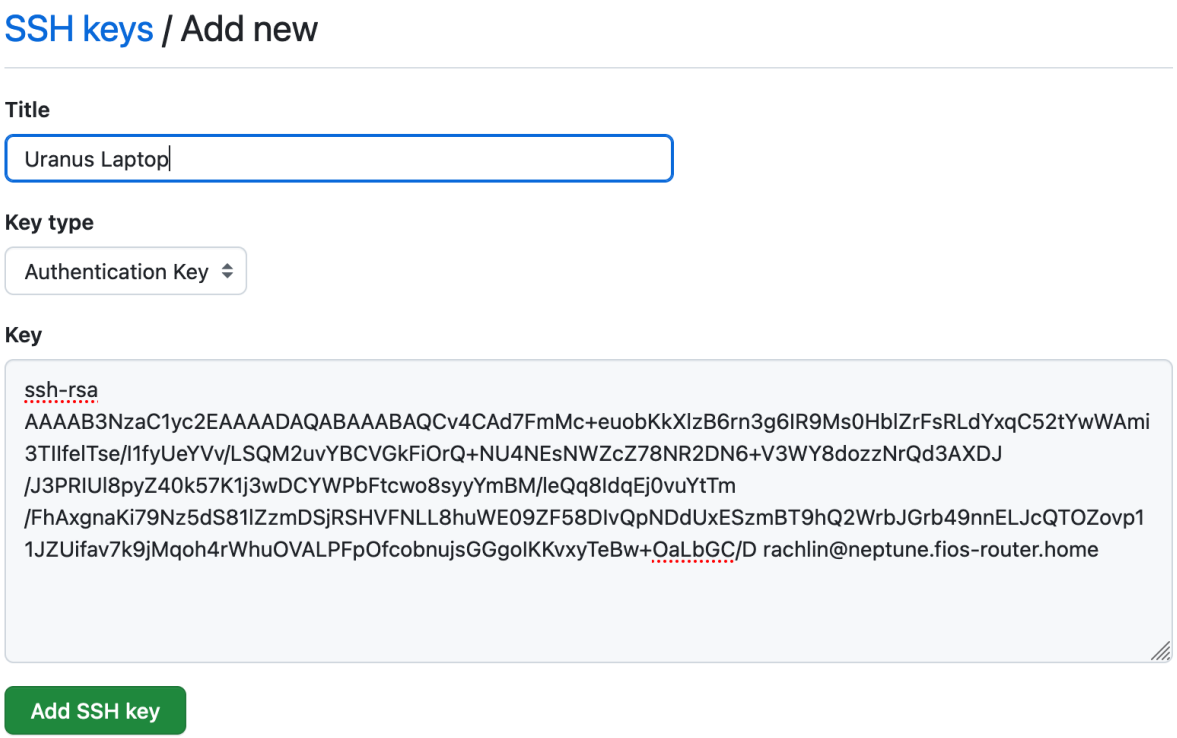
You can leave the passphrase empty for no passphrase.

Your public and private ssh key

Your newly-generated public and private SSH key live in your home directory inside a .ssh folder. (The dot before the folder name indicates that this is a hidden folder.). I don't mind showing you my public key (**id_rsa.pub**) but my private key (**id_rsa**) is for my eyes only! Your keys might be named something different. Just look for the two files, one of which has the **.pub** extension. THAT's your public key!



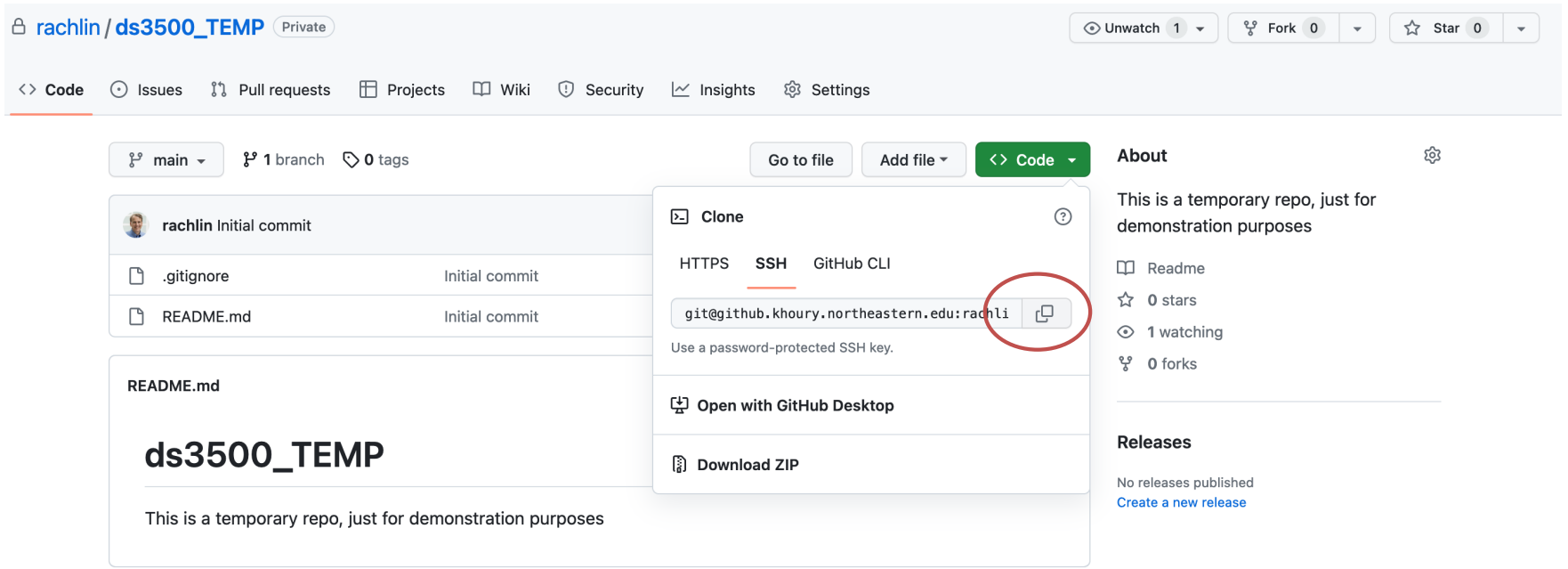
Registering the public SSH key



One the key is registered
I can run git commands without having to enter a username and password.

Let’s clone our test repo

Pull down the green “Code” button, select SSH, and copy that address to the clipboard.



Now clone the repo

```
(ds) [542 uranus:~ ] cd Documents
(ds) [543 uranus:Documents ] cd courses
(ds) [544 uranus:courses ] git clone git@github.khoury.northeastern.edu:rachlin/ds3500_TEMP.git
Cloning into 'ds3500_TEMP'...
remote: Enumerating objects: 4, done.
remote: Counting objects: 100% (4/4), done.
remote: Compressing objects: 100% (4/4), done.
Receiving objects: 100% (4/4), done.
remote: Total 4 (delta 0), reused 0 (delta 0), pack-reused 0
```

Pasted the repo address
after the “git clone” command.

Adding a file to the repo

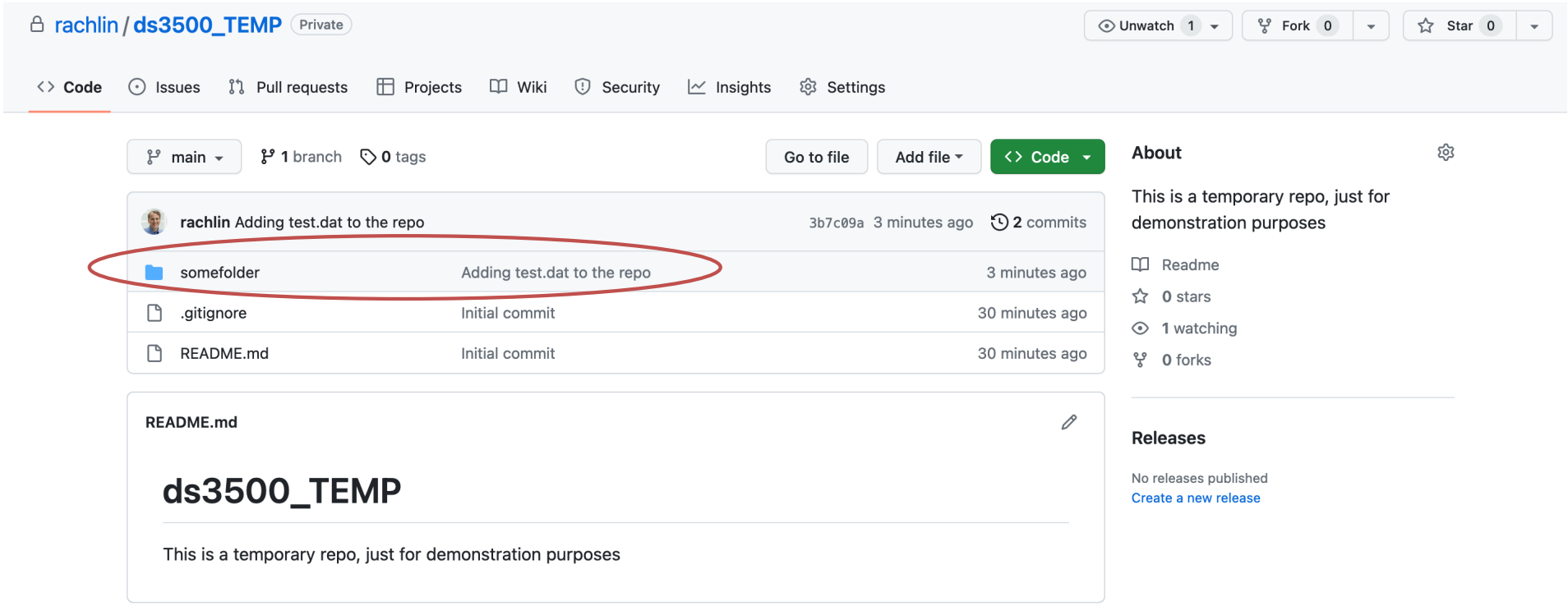
We create a subfolder and and a file called **test.dat** to the folder.

Next, we **add, commit,** and **push** the file in order to update the remote copy of the repo.

The Pro GIT book explains these commands in more detail. Please have a look.

```
(ds) [549 uranus:courses ] cd ds3500_TEMP/
(ds) [550 uranus:ds3500_TEMP ] ls
README.md
(ds) [551 uranus:ds3500_TEMP ] mkdir somefolder
(ds) [552 uranus:ds3500_TEMP ] cd somefolder
(ds) [553 uranus:somefolder ] echo "hello" > test.dat
(ds) [554 uranus:somefolder ] cat test.dat
hello
(ds) [555 uranus:somefolder ] git add test.dat
(ds) [556 uranus:somefolder ] git commit -m "Adding test.dat to the repo"
[main 3b7c09a] Adding test.dat to the repo
 1 file changed, 1 insertion(+)
 create mode 100644 somefolder/test.dat
(ds) [557 uranus:somefolder ] git push
Enumerating objects: 5, done.
Counting objects: 100% (5/5), done.
Delta compression using up to 8 threads
Compressing objects: 100% (2/2), done.
Writing objects: 100% (4/4), 382 bytes | 382.00 KiB/s, done.
Total 4 (delta 0), reused 0 (delta 0)
To github.khoury.northeastern.edu:rachlin/ds3500_TEMP.git
   aeddc68..3b7c09a  main -> main
(ds) [558 uranus:somefolder ]
```

Refresh our repo page on the git server



Obligatory XKCD

Reliability, Scalability, and Maintainability

Challenges

- **Reliability**: The system should continue to work *correctly* in response to hardware, software, or user errors

- **Scalability**: As the system grows (data volume, traffic, or complexity) there should be reasonable ways of dealing with that growth. The design should be *elastic.*

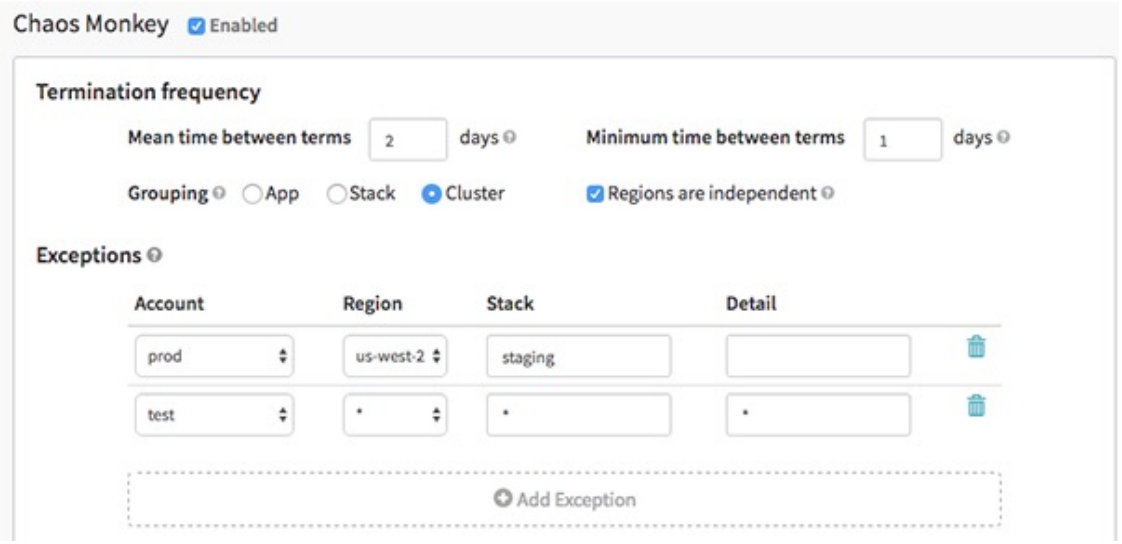
- **Maintainability**: Productively work on the system as people come and go. Add new features to adapt to changing requirements.

What is reliability?

- **Predictable**: Application performs as expected
- **Fault-tolerant:** Application copes with human error & hardware failures.
- **Performant**: Performance is adequate under expected load and data volume
- **Secure**: System prevents unauthorized access

Reliability

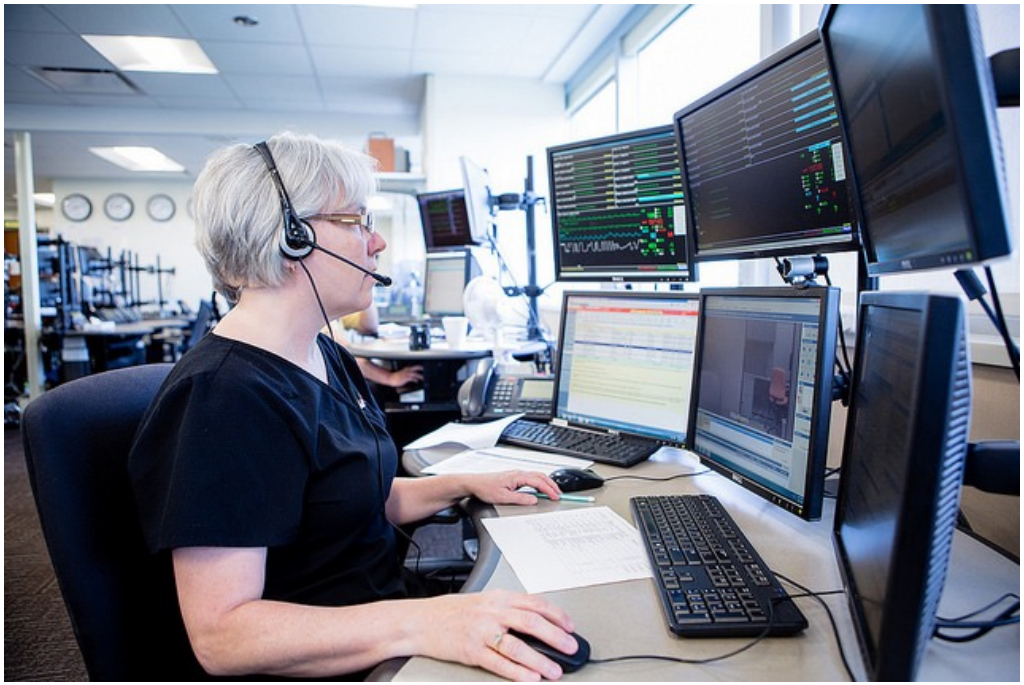
- **Faults** are a deviation in the spec of one particular component of the system. **Failures** cause the whole system to stop, requiring user intervention.
- A system is *fault-tolerant* if it anticipates and copes with certain kind of faults.
- One way to design fault-tolerant systems is to induce them deliberately! (e.g., submit bad input by the user, shut down a process, etc.)



Netflix Chaos Monkey

Reliability: Human Errors

- Application / service / network configuration errors
- Balance flexibility with restrictions aimed at encouraging users to do the right thing
- Sandbox testing/ Automated unit testing to identify edge cases
- Automated rollout / rollback of code changes (DevOps)
- Monitoring / Dashboards / Telemetry for error detection, performance tracking



Maintainability

Software cost breakdown:

Initial development: ~10-20%
Error correction: ~10-20%
On-going Maintenance: ~60-80%

Operability: Make it easy for operations teams to keep system running

Simplicity: Make it easy for engineers to understand

Evolvability: Make it easy for engineers to modify in response to changing requirements *(extensibility / plasticity)*

Python Exception Hierarchy

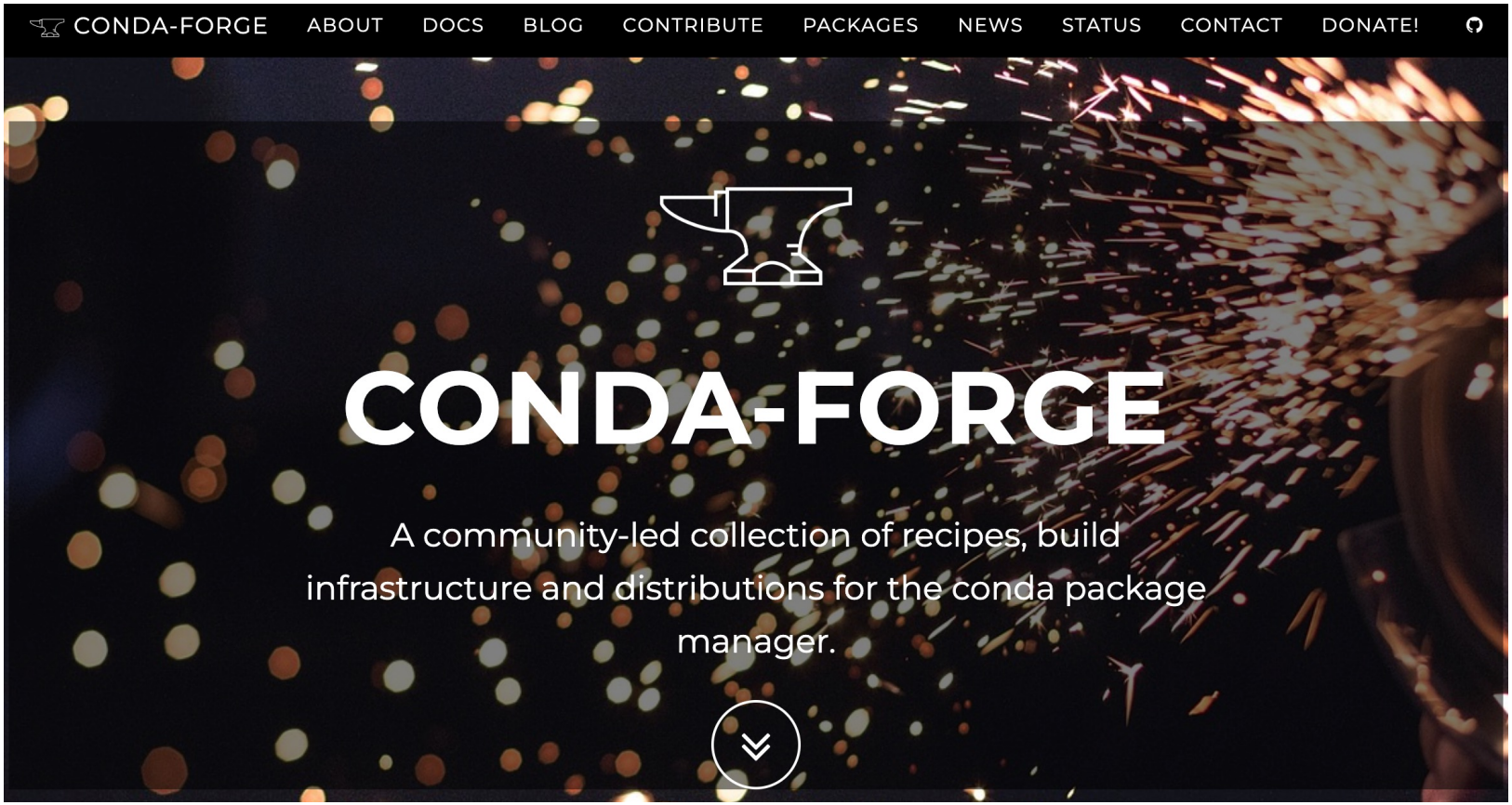
```
BaseException
 +-- SystemExit
 +-- KeyboardInterrupt
 +-- GeneratorExit
 +-- Exception
      +-- StopIteration
      +-- StopAsyncIteration
      +-- ArithmeticError
      |    +-- FloatingPointError
      |    +-- OverflowError
      |    +-- ZeroDivisionError
      +-- AssertionError
      +-- AttributeError
      +-- BufferError
      +-- EOFError
      +-- ImportError
      |    +-- ModuleNotFoundError
      +-- LookupError
      |    +-- IndexError
      |    +-- KeyError
      +-- MemoryError
      +-- NameError
      |    +-- UnboundLocalError
      +-- OSError
      |    +-- BlockingIOError
      |    +-- ChildProcessError
      |    +-- ConnectionError
      |    |    +-- BrokenPipeError
      |    |    +-- ConnectionAbortedError
      |    |    +-- ConnectionRefusedError
      |    |    +-- ConnectionResetError
      |    +-- FileExistsError
      |    +-- FileNotFoundError
      |    +-- InterruptedError
      |    +-- IsADirectoryError
      |    +-- NotADirectoryError
      |    +-- PermissionError
      |    +-- ProcessLookupError
      |    +-- TimeoutError
      +-- ReferenceError
      +-- RuntimeError
      |    +-- NotImplementedError
      |    +-- RecursionError
      +-- SyntaxError
      |    +-- IndentationError
      |         +-- TabError
      +-- SystemError
      +-- TypeError
      +-- ValueError
      |    +-- UnicodeError
      |         +-- UnicodeDecodeError
      |         +-- UnicodeEncodeError
      |         +-- UnicodeTranslateError
      +-- Warning
           +-- DeprecationWarning
           +-- PendingDeprecationWarning
           +-- RuntimeWarning
           +-- SyntaxWarning
           +-- UserWarning
           +-- FutureWarning
           +-- ImportWarning
           +-- UnicodeWarning
           +-- BytesWarning
           +-- ResourceWarning
```

In Python, all exceptions must be instances of a class that derives from BaseException. In a try statement with an except clause that mentions a particular class, that clause also handles any exception classes derived from that class (but not exception classes from which *it* is derived).

Advanced Visualization with Plotly

Northeastern University

Conda Forge (conda-forge.org)



Why use the conda-forge channel?

The conda team, from Anaconda, Inc., packages a multitude of packages and provides them to all users free of charge in their `default` channel.

But what if a package you are looking for is not in the default channel? In the past users only had the option to create an Anaconda Cloud account and create their own channel.

conda-forge is a GitHub organization containing repositories of conda recipes. Thanks to some awesome continuous integration providers (AppVeyor, Azure Pipelines, CircleCI and TravisCI), each repository, also known as a feedstock, automatically builds its own recipe in a clean and repeatable way on Windows, Linux and OSX.

```
conda config --add channels conda-forge
conda config --set channel_priority strict
conda install <package-name>
```

Channel Priority

Documentation: **conda config --describe channel_priority**

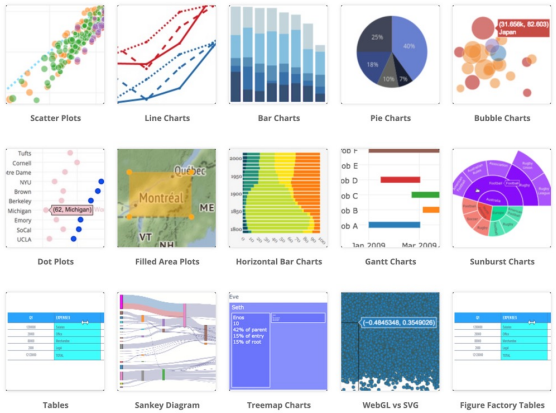
Setting the channel priority: **conda config --set channel_priority <strict | flexible | disabled>**

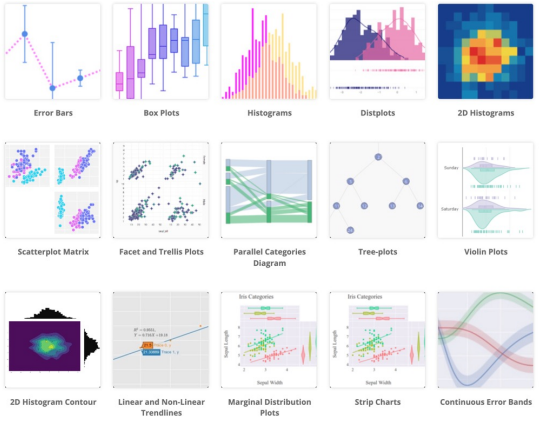
strict: Packages in lower priority channels are not considered if a package with the same name appears in a higher priority channel**.** (Use only the first channel that has the package to resolve any dependencies.)

flexible: With flexible channel priority, the solver may reach into lower priority channels to fulfill dependencies, rather than raising an unsatisfiable error. (A higher priority channel with an earlier package version takes precedence over a lower priority channel with a newer package version.

disabled: With channel priority disabled, package version takes precedence, and the configured priority of channels is used only to break ties.

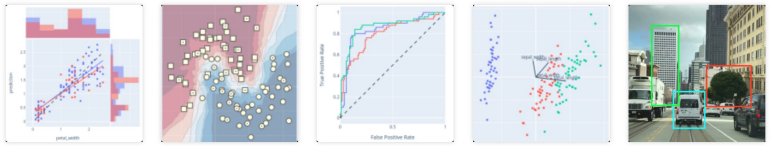
A gallery of possibilities: https://plotly.com/python/

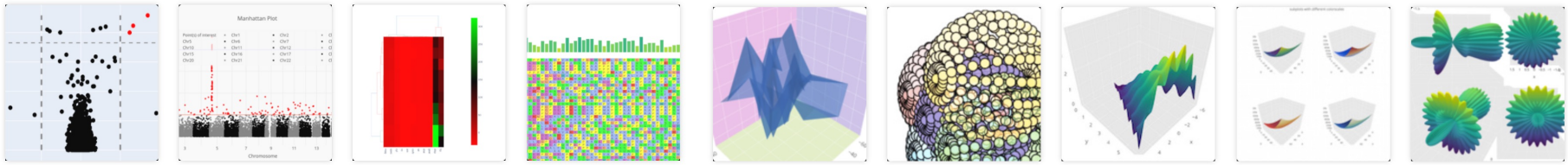




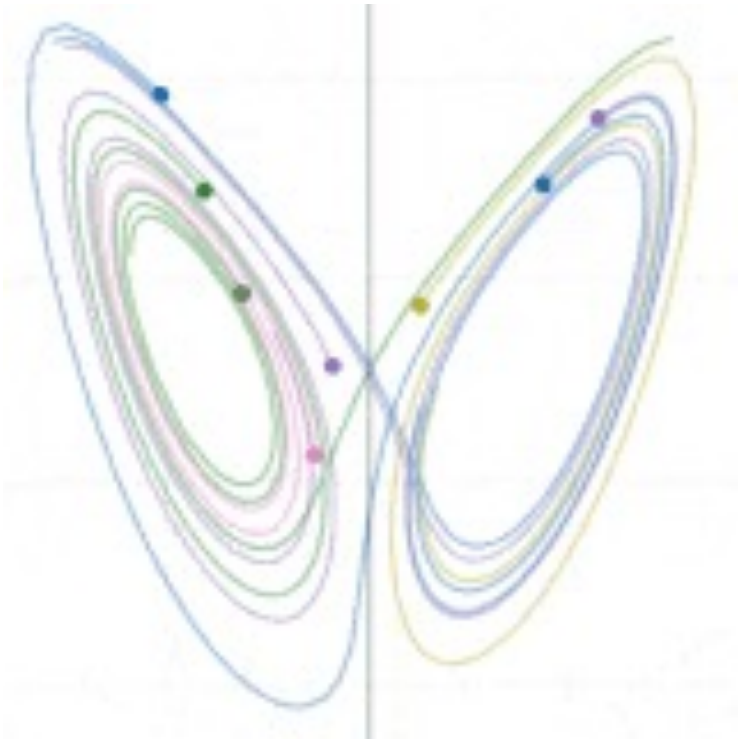
Artificial Intelligence and Machine Learning

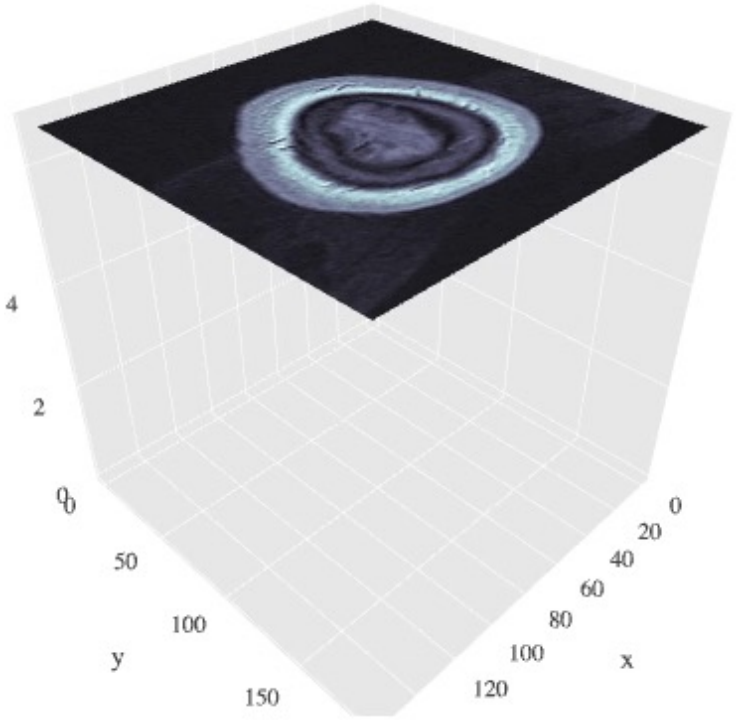
More AI and ML »





Animations!





Is Plotly for Python Free?

Yes. Plotly for Python is free and open-source software, licensed under the **MIT license**. It costs nothing to install and use. You can view the source, report issues or contribute using our Github repository.

Can I use Plotly for Python without signing up to any service?

Yes. You can use Plotly for Python to make, view, and distribute charts and maps without registering for any service, obtaining any token, or creating any account. The one exception is that to view tile maps which use tiles from the Mapbox service (which is optional, as you can use other tile servers), you will need to have a Mapbox token.

Can I use Plotly for Python offline, without being connected to the internet?

Yes. You can use Plotly for Python to make, view, and distribute graphics totally offline. The one exception is that to view tile maps which use tiles from a cloud-hosted service, such as Open Street Maps or Mapbox, you will need a connection to that service. You can view tile maps totally offline if you run your own local tile server and use its tiles.

Free Software: Free as in beer / Free as in speech

Free as in Beer

- The software doesn't cost you anything (monetarily) to use.
- There are still restrictions on **how** you use the software – for example you can't necessarily view, modify, or redistribute the source code.

Free as in Speech

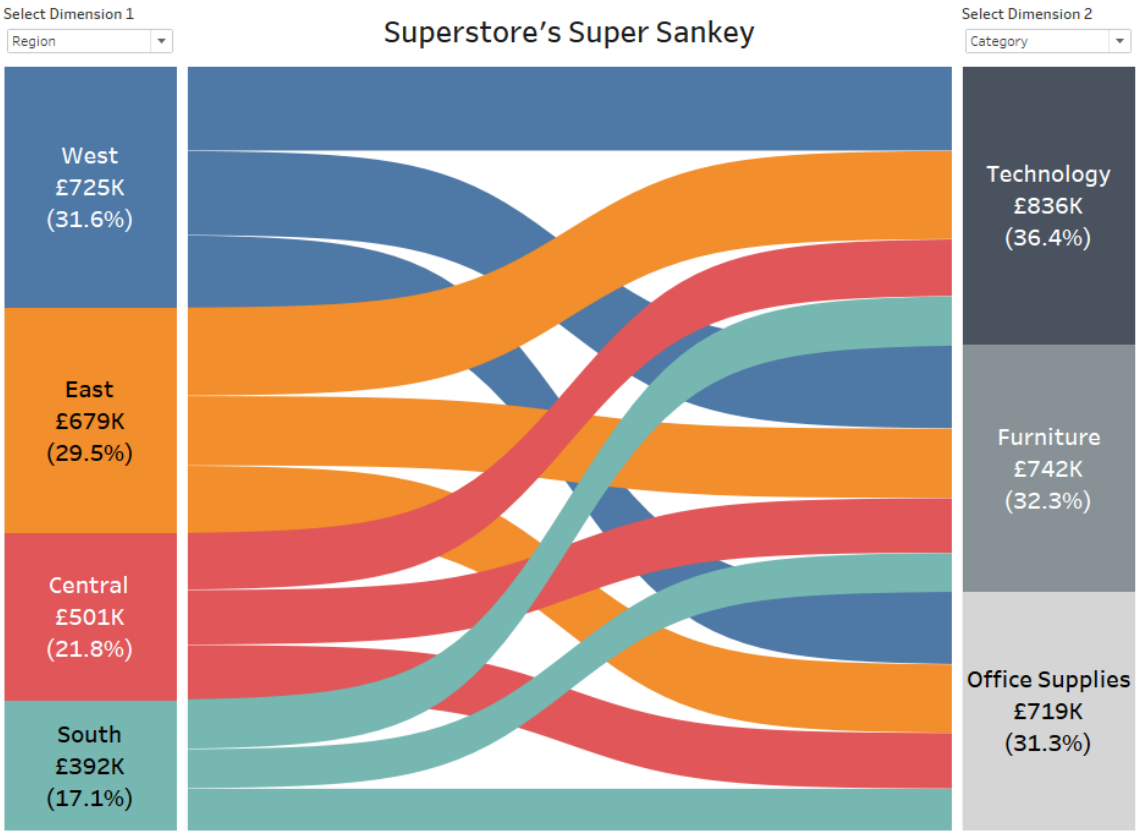
- You are at liberty to use the software however you like.
- You can inspect the source code.
- You can redistribute or repackage the code.
- You can create your own improved versions.

Installation

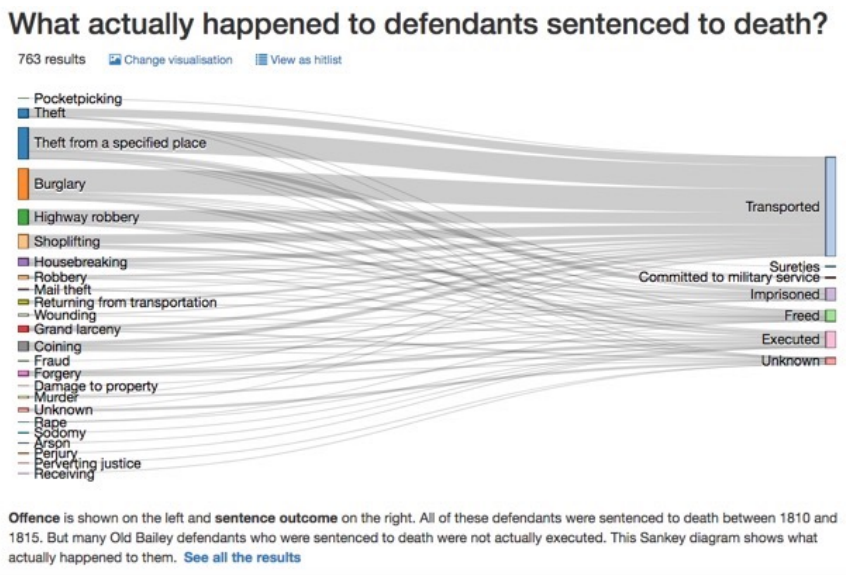
$ conda install –c conda-forge plotly

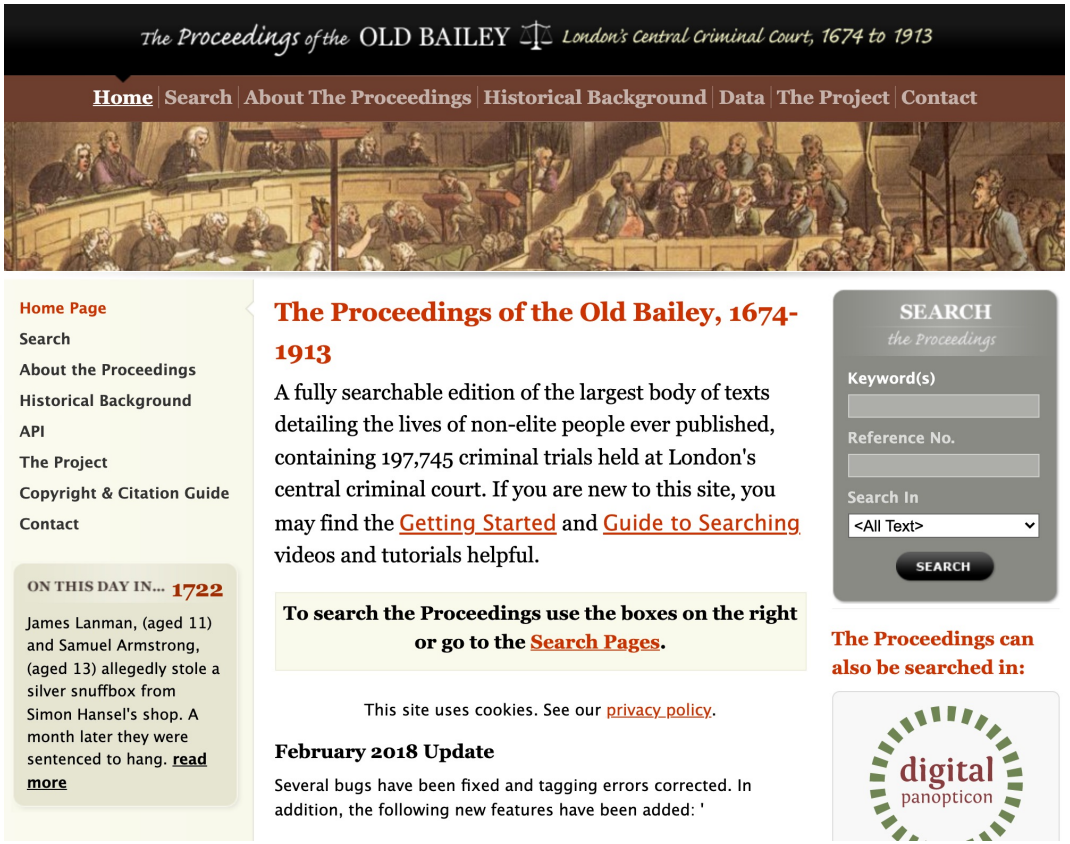

```
The following packages will be downloaded:

    package                    |            build
    ---------------------------|-----------------
    plotly-5.12.0              |     pyhd8ed1ab_1         5.7 MB  conda-forge
    ------------------------------------------------------------
                                           Total:         5.7 MB

The following NEW packages will be INSTALLED:

  plotly             conda-forge/noarch::plotly-5.12.0-pyhd8ed1ab_1 None
  tenacity           conda-forge/noarch::tenacity-8.1.0-pyhd8ed1ab_0 None


Proceed ([y]/n)?


Downloading and Extracting Packages
plotly-5.12.0        | 5.7 MB    | ##################################### | 100%
Preparing transaction: done
Verifying transaction: done
Executing transaction: done
Retrieving notices: ...working... done
(ds) [530 uranus:~ ]
```

Sankey Diagrams: Market Analysis



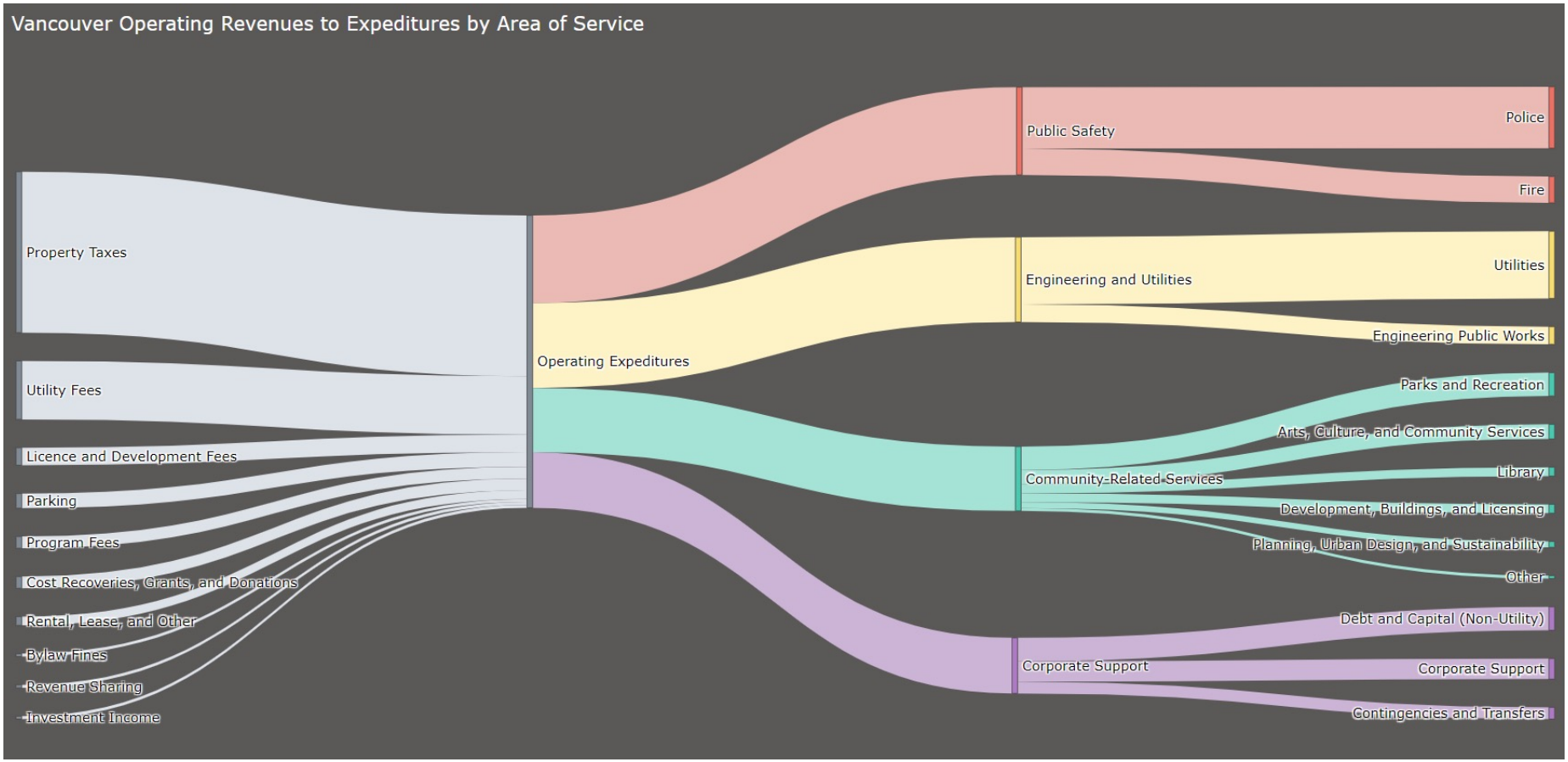
Crime and Punishment in the Old Bailey



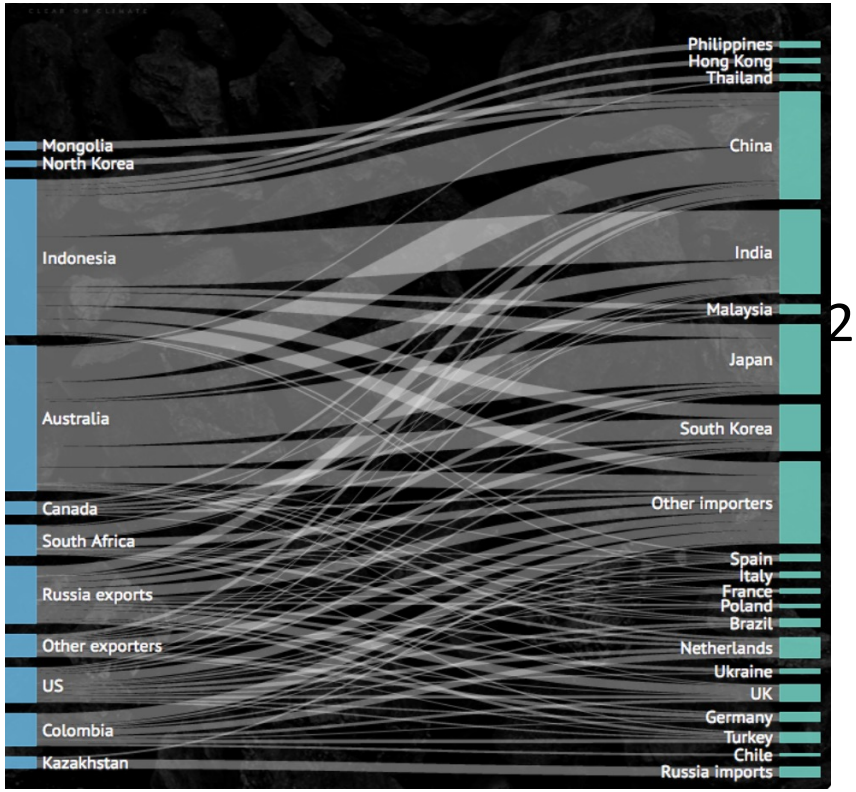


Northeastern University

Sankey Diagrams: Analyzing Expenses

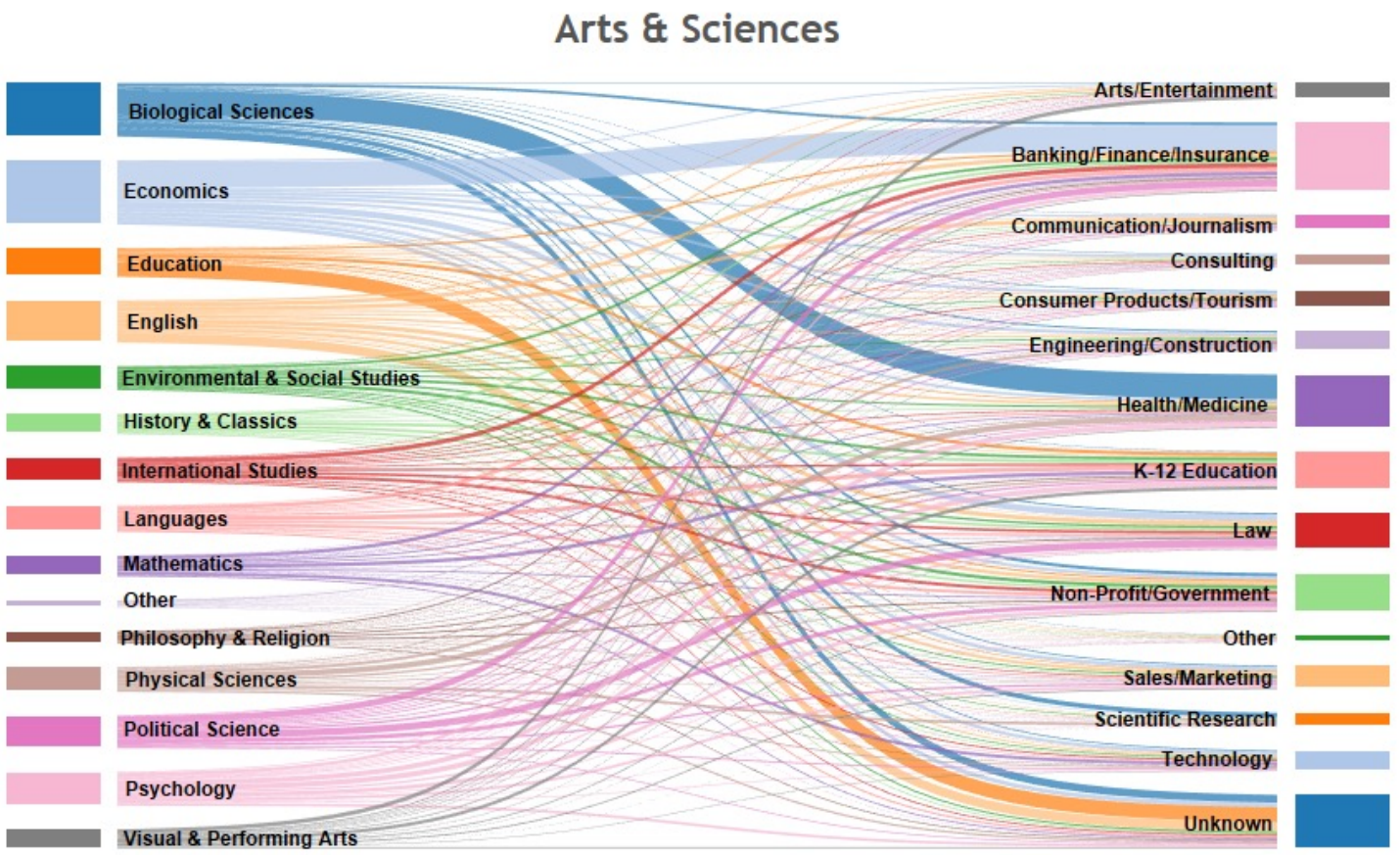


Sankey Diagrams: Trade

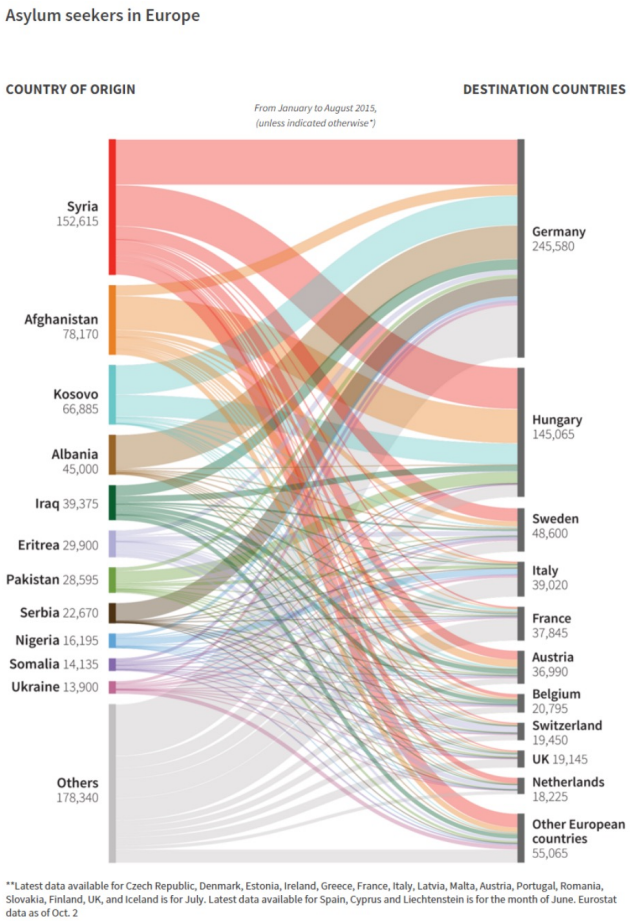


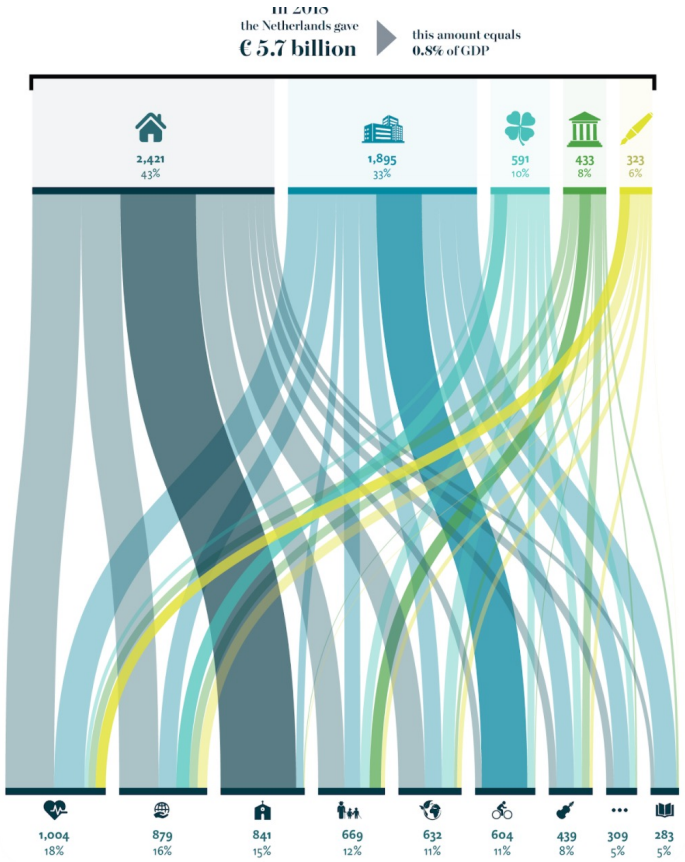
2014 Coal Exports and Imports

Sankey Diagrams: The value of a liberal arts education



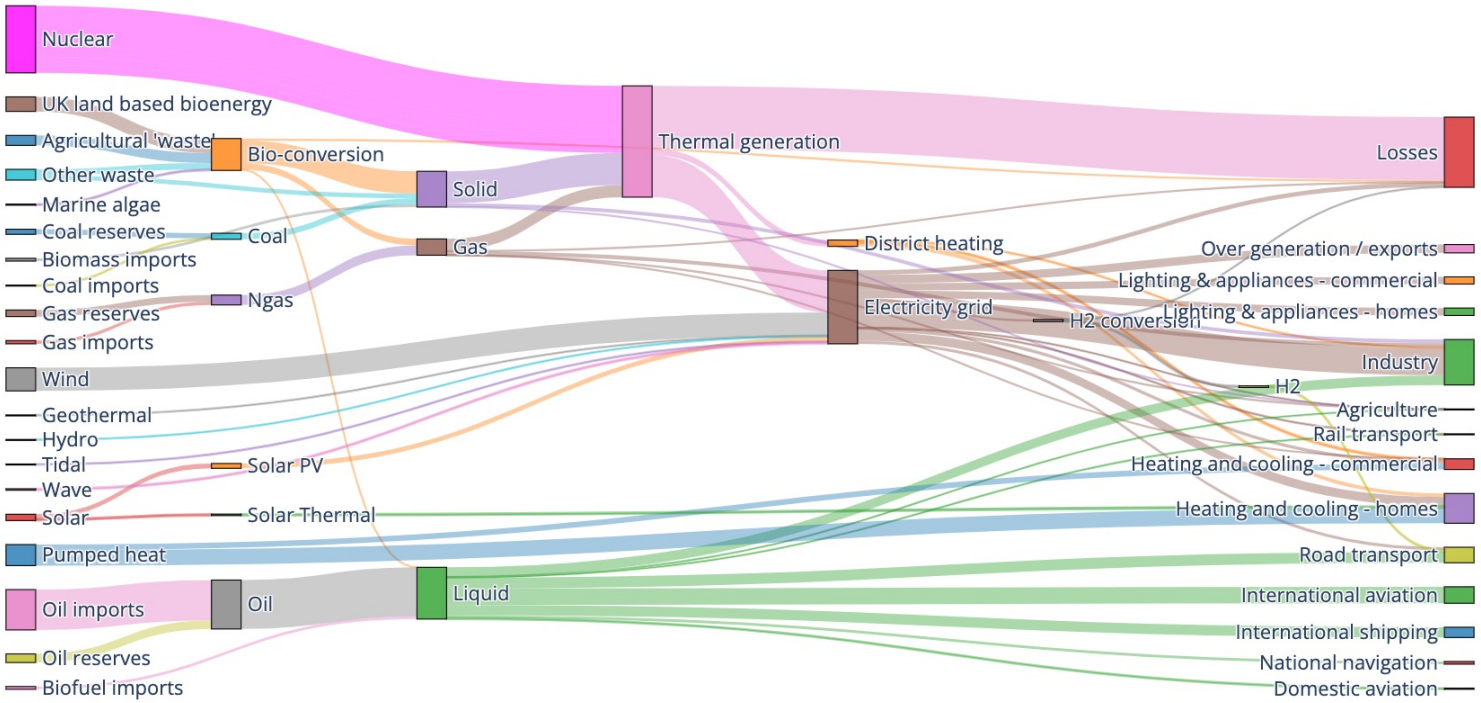
Sankey Diagrams: Migration Patterns



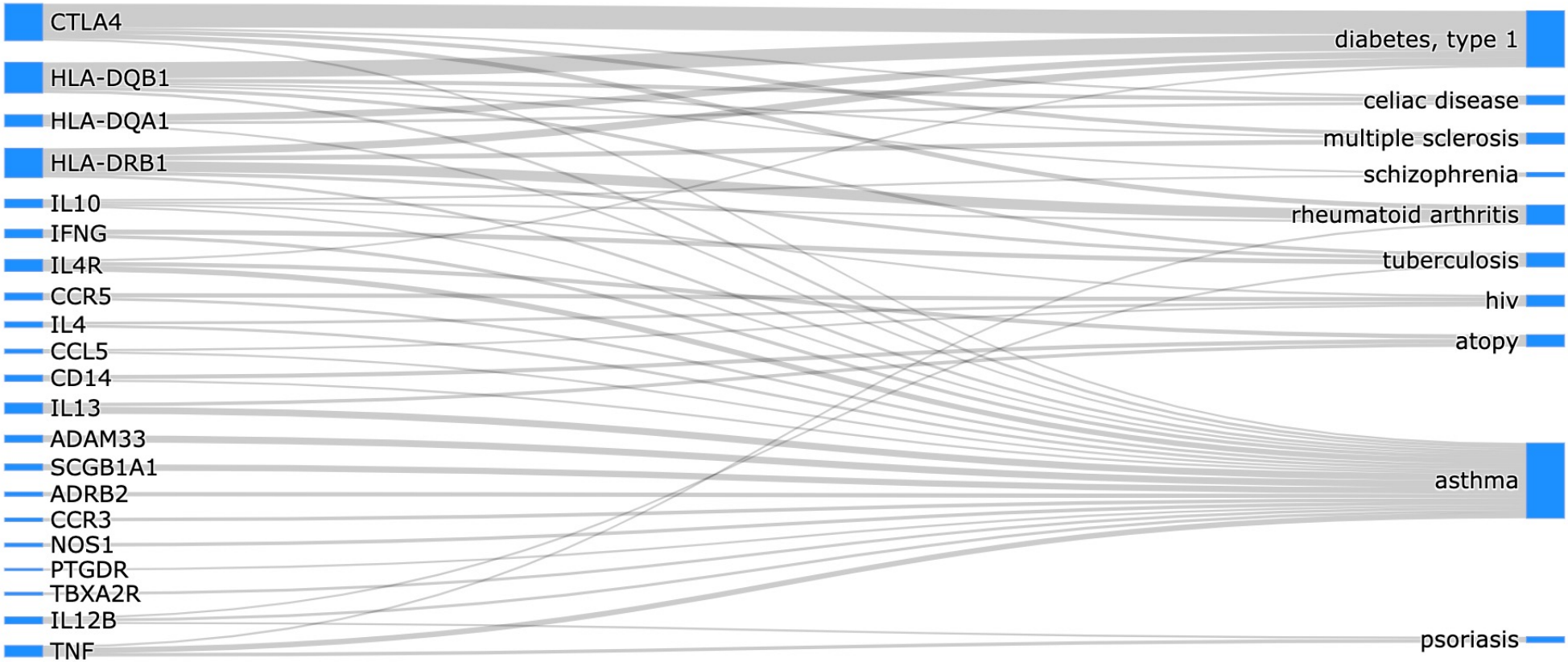


Energy Forecasting

Energy forecast for 2050
Source: Department of Energy & Climate Change, Tom Counsell via Mike Bostock



Sankey: The Genetic Association Database



Links between Asthma and Type 1 Diabetes

This Issue | Views 3,824 | Citations 5 | Altmetric 40 | Comments 1

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Original Investigation | Pediatrics

March 12, 2020

Familial Coaggregation of Asthma and Type 1 Diabetes in Children

Awad I. Smew, MD[1]; Cecilia Lundholm, MSc[1]; Lars Sävendahl, MD, PhD[2]; et al

Author Affiliations | Article Information

JAMA Netw Open. 2020;3(3):e200834. doi:10.1001/jamanetworkopen.2020.0834

Key Points | Español | 中文 (Chinese)

Question Is there an association between childhood asthma and type 1 diabetes and do shared familial factors contribute to the comorbidity?

Wolters Kluwer Medicine

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Medicine (Baltimore). 2015 Sep; 94(36): e1466. PMCID: PMC46166
Published online 2015 Sep 11. PMID: 263567
doi: 10.1097/MD.0000000000001466

Type 1 Diabetes and Increased Risk of Subsequent Asthma

A Nationwide Population-Based Cohort Study

Yung-Tsung Hsiao, MD, Wen-Chien Cheng, MD, Wei-Chih Liao, MD, Cheng-Li Lin, MS
Te-Chun Shen, MD, Wei-Chun Chen, MD, Chia-Hung Chen, MD, and Chia-Hung Kao, MD

Monitoring Editor: Zhu. Xiaolin

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Abstract

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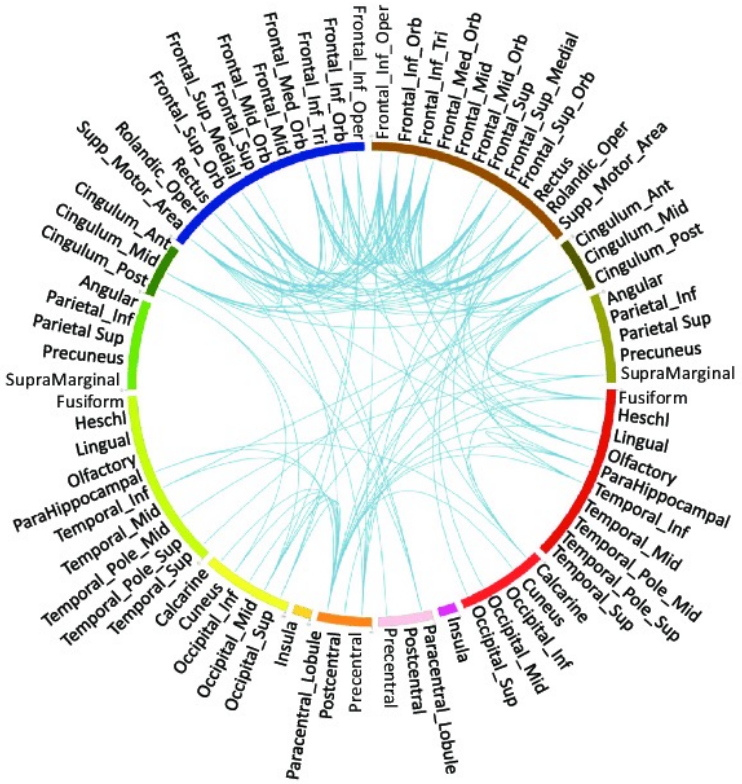
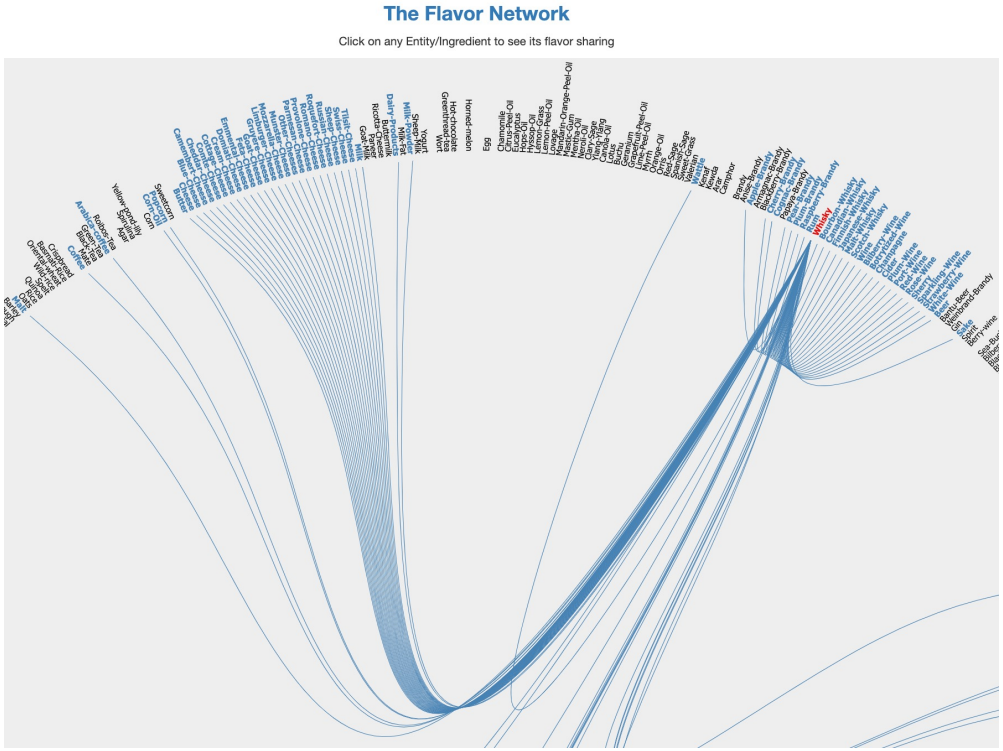
Go to:

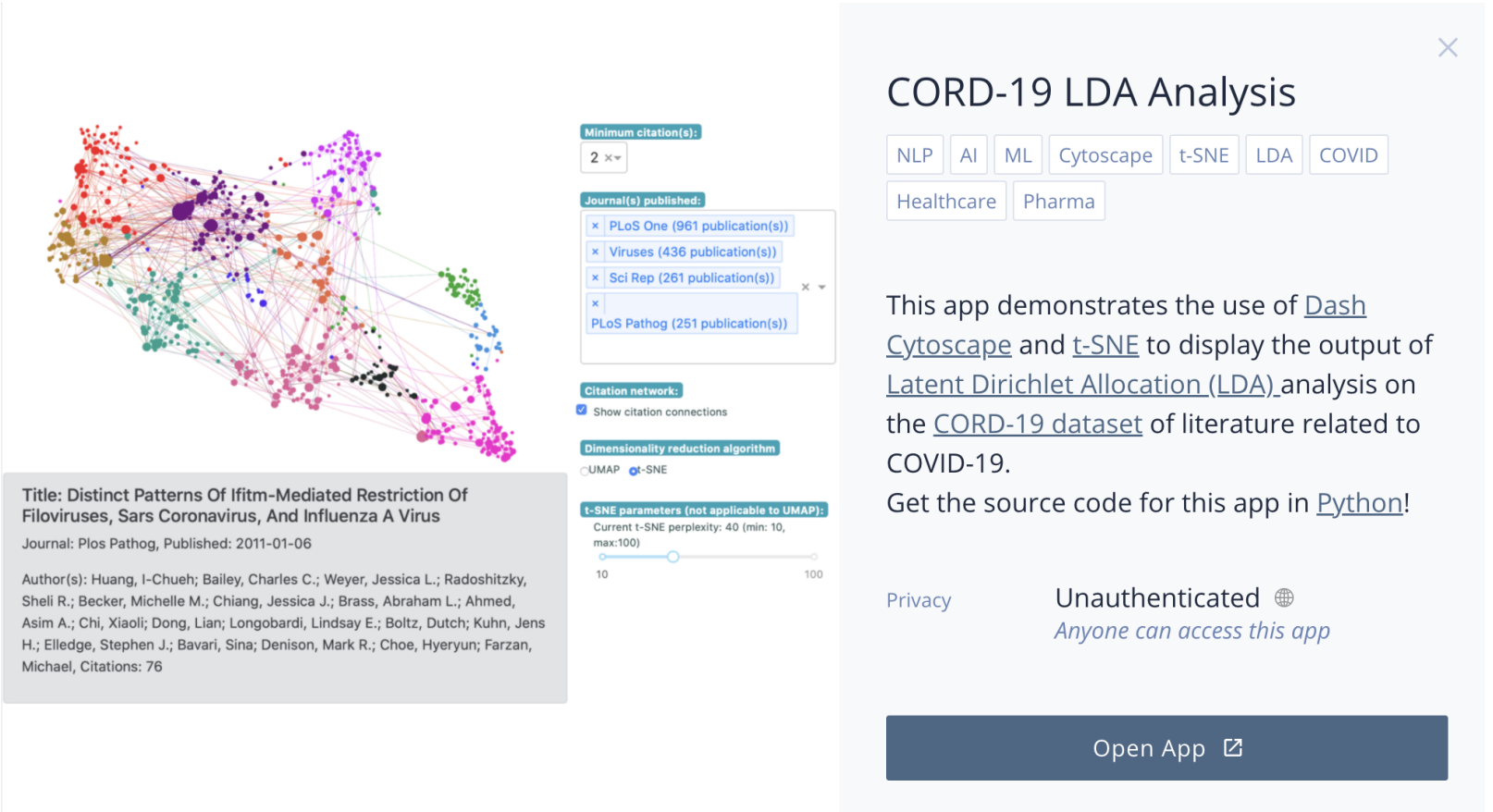
The association between type 1 diabetes mellitus (T1DM) and asthma remains controversial and has led to new interest in these 2 disorders. The purpose of this study was to examine the associations among young people with T1DM and asthma and offer a clinical demonstration of the balance between Th1 and Th2 responses.

Circle Graphs: Single-Set Sankey



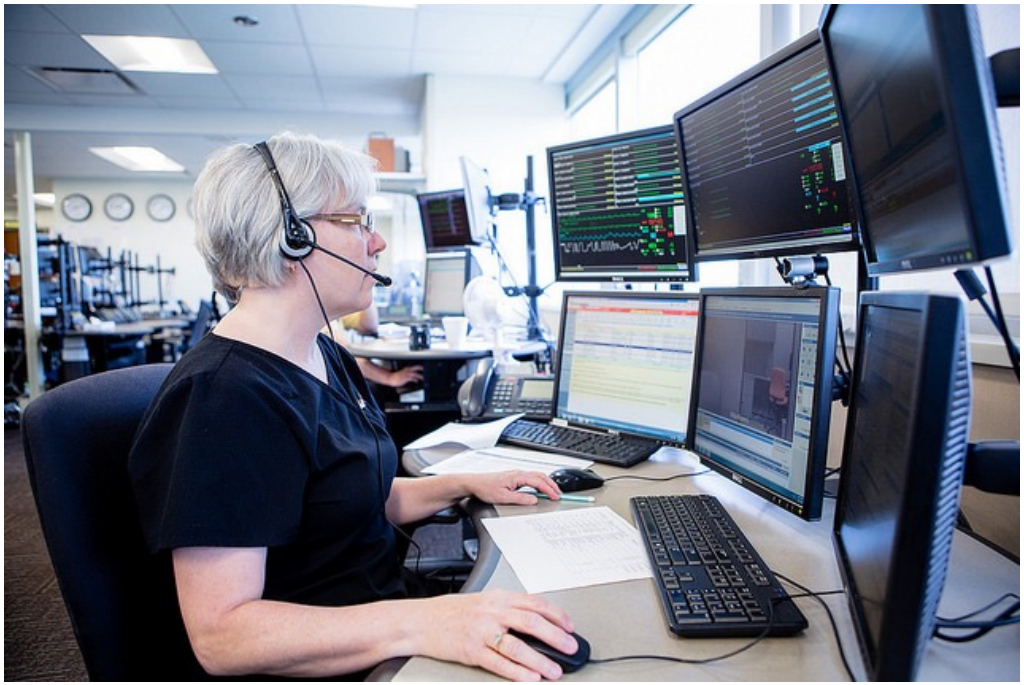


Dashboarding for Interactive Visualization

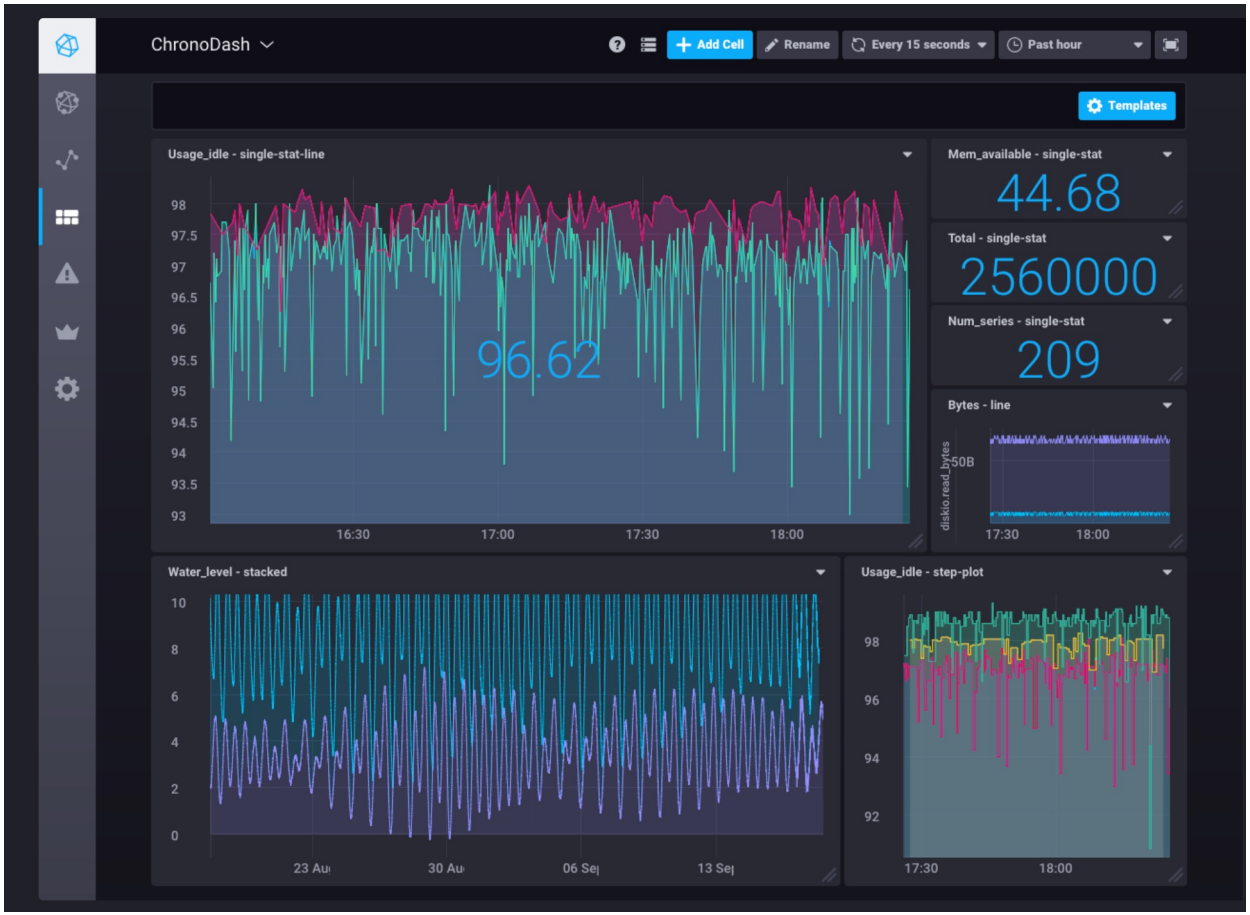


Monitoring Data Pipelines

- Application / service / network configuration errors
- Balance flexibility with restrictions aimed at encouraging users to do the right thing
- Sandbox testing/ Automated unit testing to identify edge cases
- Automated rollout / rollback of code changes (DevOps)
- Monitoring / Dashboards / Telemetry for error detection, performance tracking



Dashboards – cont.



$ conda install dash

```
The following packages will be downloaded:

    package                    |            build
    ---------------------------|-----------------
    brotli-python-1.0.9        |   py39hfd1d529_7         736 KB  conda-forge
    dash-2.3.1                 |     pyhd8ed1ab_0         7.5 MB  conda-forge
    flask-compress-1.11        |     pyhd8ed1ab_0          14 KB  conda-forge
    ------------------------------------------------------------
                                           Total:         8.3 MB

The following NEW packages will be INSTALLED:

  brotli-python      conda-forge/osx-64::brotli-python-1.0.9-py39hfd1d529_7
  dash               conda-forge/noarch::dash-2.3.1-pyhd8ed1ab_0
  flask-compress     conda-forge/noarch::flask-compress-1.11-pyhd8ed1ab_0
```

$ conda install jupyter-dash

If you prefer using Jupyter Notebooks or Jupyter Lab

```
The following packages will be downloaded:

    package                    |            build
    ---------------------------|-----------------
    ansi2html-1.7.0            |   py39h6e9494a_1          39 KB  conda-forge
    jupyter-dash-0.4.2         |     pyhd8ed1ab_1          20 KB  conda-forge
    retrying-1.3.3             |             py_2          11 KB  conda-forge
    ------------------------------------------------------------
                                           Total:          71 KB

The following NEW packages will be INSTALLED:

  ansi2html          conda-forge/osx-64::ansi2html-1.7.0-py39h6e9494a_1
  jupyter-dash       conda-forge/noarch::jupyter-dash-0.4.2-pyhd8ed1ab_1
  retrying           conda-forge/noarch::retrying-1.3.3-py_2
```

Dash installation verification: $ conda list dash

```
(base) [512 uranus:dash ] conda list dash
# packages in environment at /Users/rachlin/opt/anaconda3:
#
# Name                    Version                   Build  Channel
dash                      2.3.1              pyhd8ed1ab_0    conda-forge
jupyter-dash              0.4.2              pyhd8ed1ab_1    conda-forge
```

conda list plotly (plotly and plotly express already installed)

```
(base) [513 uranus:dash ] condalist plotly
plotly                    5.5.0              pyhd8ed1ab_0    conda-forge
plotly_express            0.4.1                     py_0    conda-forge
```

Dash HTML Components

```python
from dash import html

html.Div([
    html.H1('Hello Dash'),
    html.Div([
        html.P('Dash converts Python classes into HTML'),
        html.P("This conversion happens behind the scenes by Dash's JavaScript front-end")
    ])
])
```

which gets converted (behind the scenes) into the following HTML in your web-app:

```html
<div>
    <h1>Hello Dash</h1>
    <div>
        <p>Dash converts Python classes into HTML</p>
        <p>This conversion happens behind the scenes by Dash's JavaScript front-end</p>
    </div>
</div>
```

Source: https://dash.plotly.com/dash-html-components

Dash Core Components

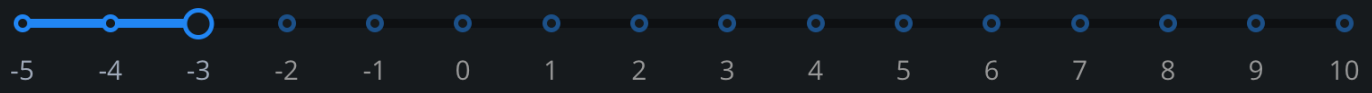
Dropdown

```
from dash import Dash, html, dcc

app = Dash(__name__)

app.layout = html.Div([
    dcc.Dropdown(['New York City', 'Montréal', 'San Francisco'], 'Montréal')
])

if __name__ == '__main__':
    app.run_server(debug=True)
```

Dash Core Components → localhost:8050

Slider

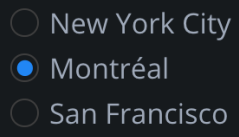
```
from dash import Dash, dcc, html

app = Dash(__name__)

app.layout = html.Div([
    dcc.Slider(-5, 10, 1, value=-3)
])

if __name__ == '__main__':
    app.run_server(debug=True)
```



Dash Core Components

Radio Items

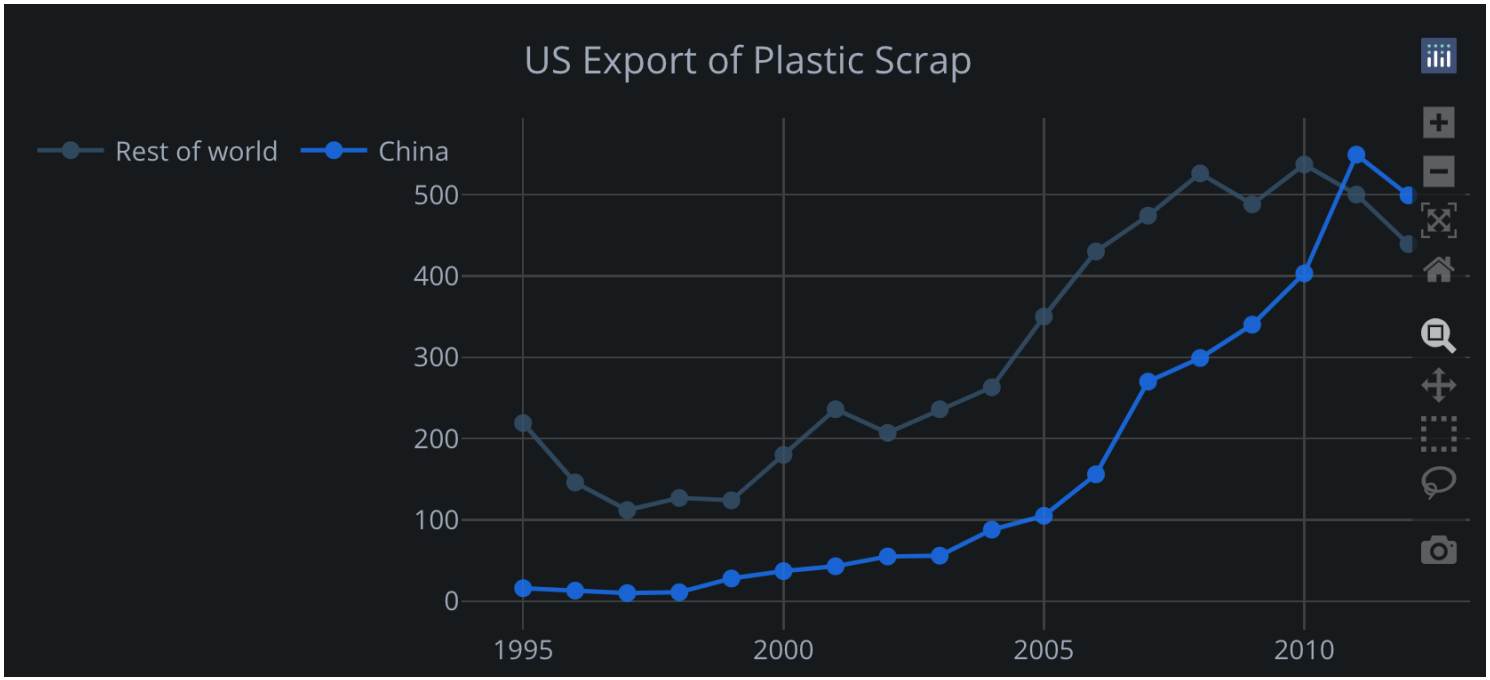
```
from dash import Dash, dcc, html

app = Dash(__name__)

app.layout = html.Div([
    dcc.RadioItems(['New York City', 'Montréal', 'San Francisco'], 'Montréal')
])

if __name__ == '__main__':
    app.run_server(debug=True)
```



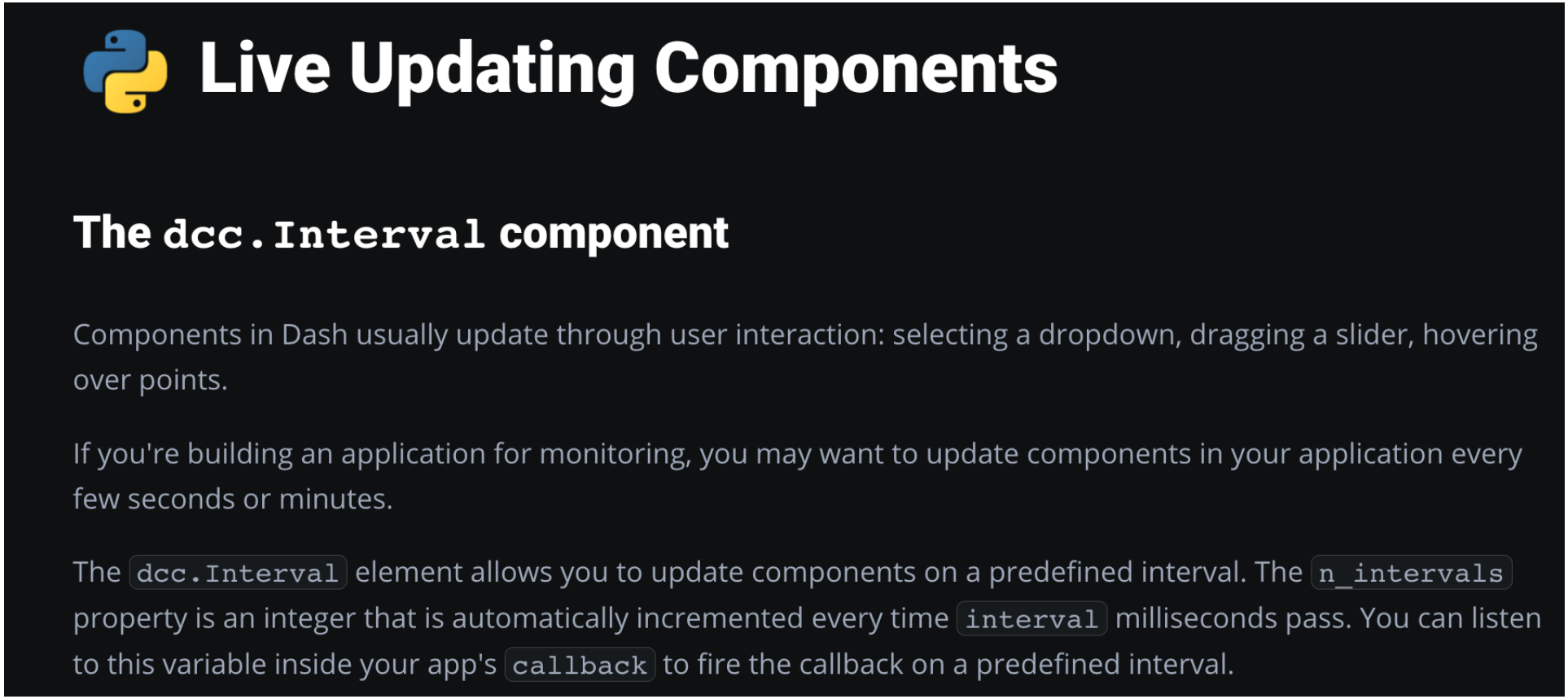
Graphs! (Including our friend, the SanKey Diagram)

Graphs

The `Graph` component shares the same syntax as the open-source `plotly.py` library. View the **plotly.py docs** to learn more.



Live Updates

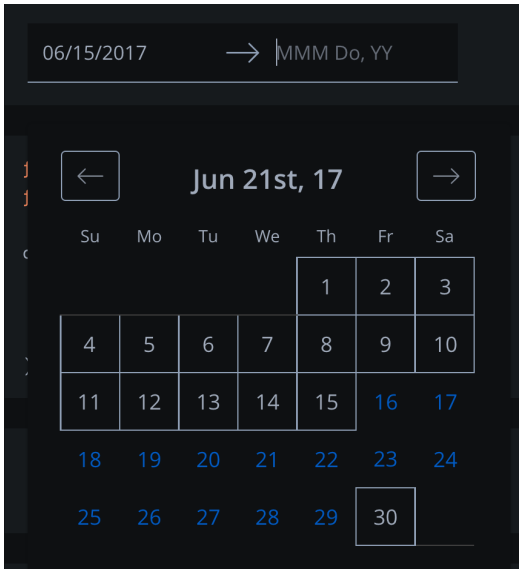


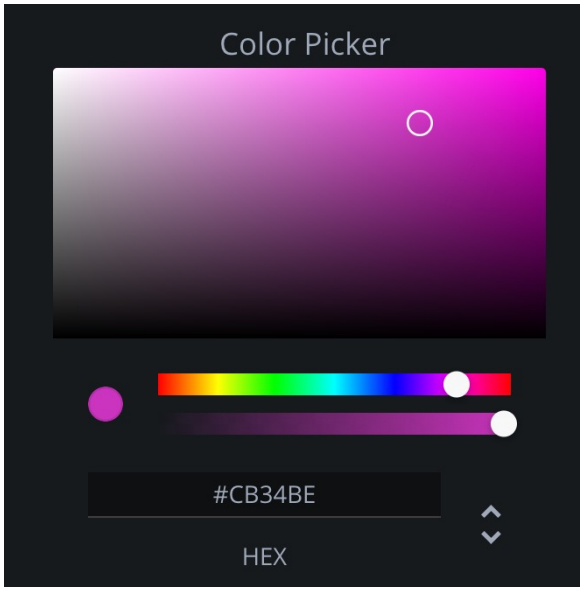
Dash Tables

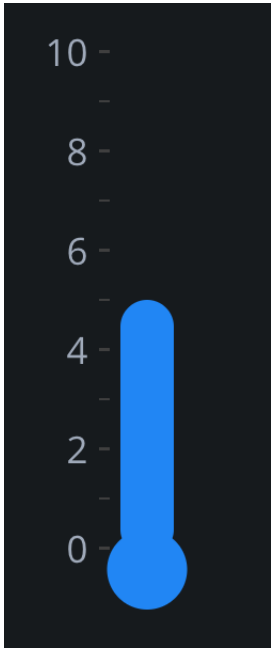
index	continent	country	gdpPercap	lifeExp	pop
1	Asia	Afghanistan	974.5803384	43.828	31889923
2	Europe	Albania	5937.029525999999	76.423	3600523
3	Africa	Algeria	6223.367465	72.301	33333216
4	Africa	Angola	4797.231267	42.731	12420476
5	Americas	Argentina	12779.37964	75.32	40301927

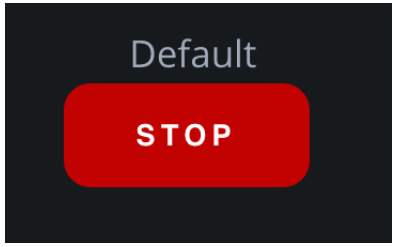
« ‹ 1 › »

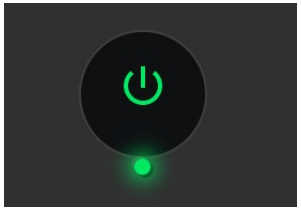
Dash DAQ: Web development framework











Callbacks

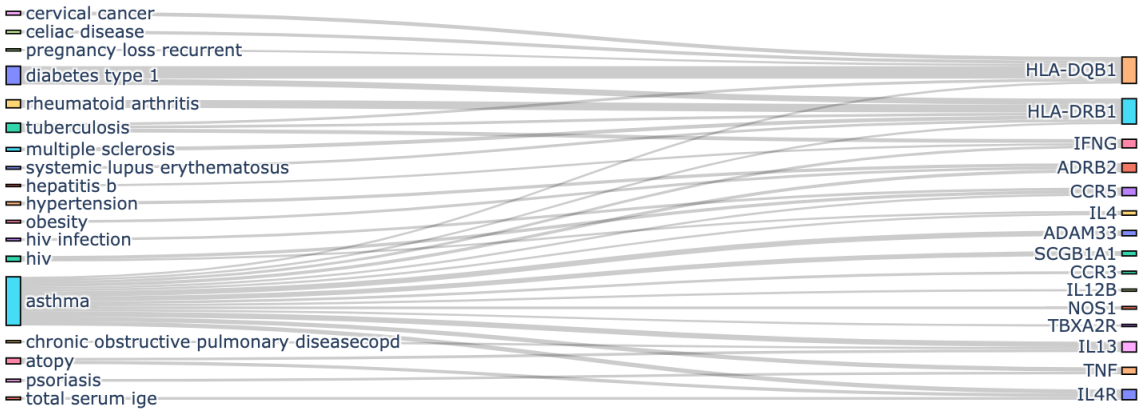
Callbacks make your dashboards interactive

```python
from dash import Dash, dcc, html, Input, Output

app = Dash(__name__)
app.layout = html.Div([
    dcc.Dropdown(['NYC', 'MTL', 'SF'], 'NYC', id='demo-dropdown'),
    html.Div(id='dd-output-container')
])


@app.callback(
    Output('dd-output-container', 'children'),
    Input('demo-dropdown', 'value')
)
def update_output(value):
    return f'You have selected {value}'


if __name__ == '__main__':
    app.run_server(debug=True)
```

NYC

You have selected NYC

Putting it all together…..



Select phenotype:

asthma

Minimum number of confirming publications

1 2 3 4 5 6 7 8 9 10

Northeastern University

An interactive database-driven web application for visualizing gene-disease associations and identifying related phenotypes based on gene overlap.

Array Processing with Numpy

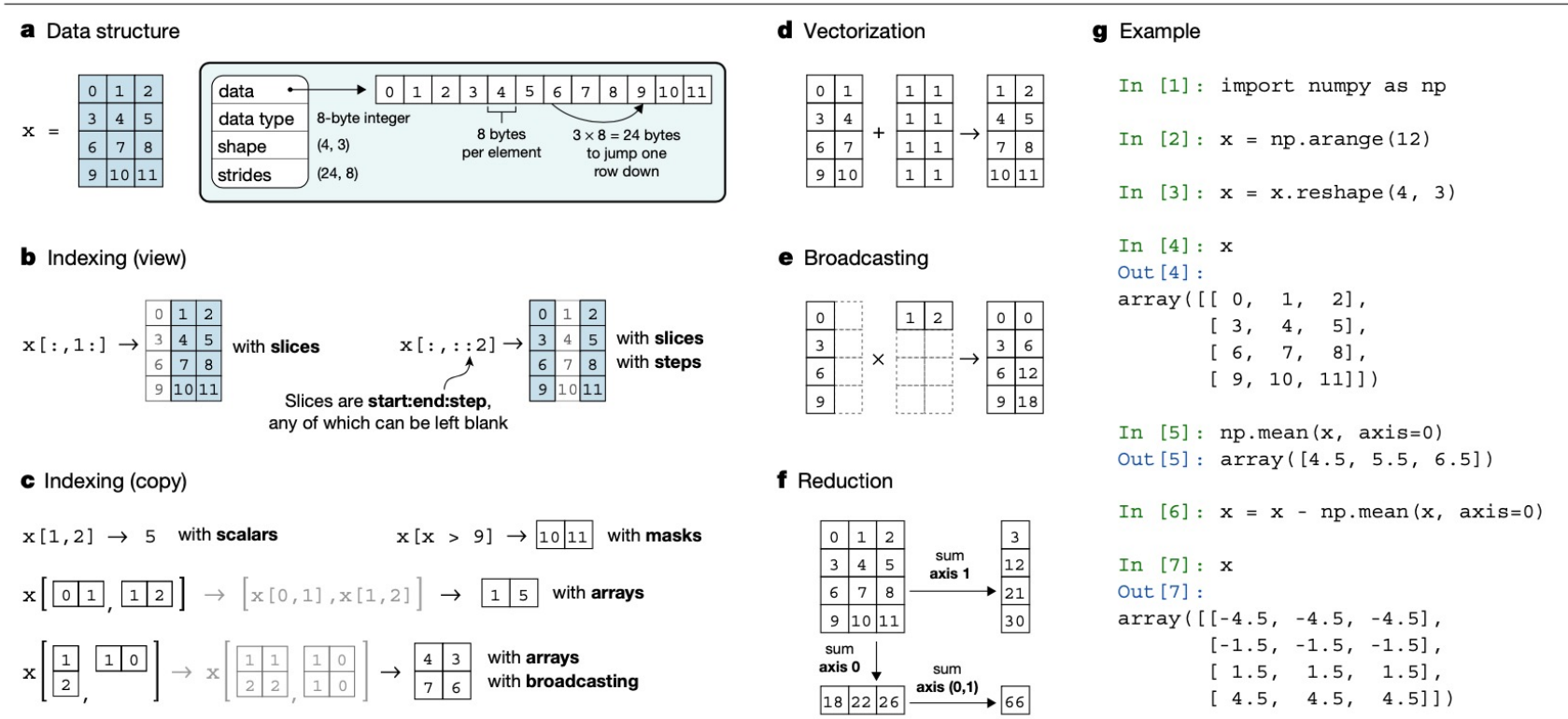
(DS2500 Review)

Northeastern University

Types of Arrays

Type	Description	Advantage	Disadvantage	
Lists	Standard built-in python list collection	Simplicity Non-homogeneous	Slower performance Limited functionality	[[1, 2, 3], [4, 5, 6]]
ndarray (NumPy)	High-performance array module for scientific applications.	High performance Flexible operations	Homogeneous values Numeric indexing only	array([1,2,3])
Series (Pandas)	Enhanced one-dimensional array	Custom indexing Missing-value support Many capabilities	Complexity	Wally 87 Eva 100 Sam 94 dtype: int64
DataFrame (Pandas)	Enhanced two-dimensional array (e.g., “tables”)	Flexible support for manipulating tabular data: filtering, sorting	Complexity	A B C 0 10 True 5.4 1 15 False 8.8 2 12 False 6.6

Array operations




```
In [1]: import numpy as np

In [2]: x = np.arange(12)

In [3]: x = x.reshape(4, 3)

In [4]: x
Out[4]:
array([[ 0,  1,  2],
       [ 3,  4,  5],
       [ 6,  7,  8],
       [ 9, 10, 11]])

In [5]: np.mean(x, axis=0)
Out[5]: array([4.5, 5.5, 6.5])

In [6]: x = x - np.mean(x, axis=0)

In [7]: x
Out[7]:
array([[-4.5, -4.5, -4.5],
       [-1.5, -1.5, -1.5],
       [ 1.5,  1.5,  1.5],
       [ 4.5,  4.5,  4.5]])
```

Fig. 1 | The NumPy array incorporates several fundamental array concepts. **a**, The NumPy array data structure and its associated metadata fields. **b**, Indexing an array with slices and steps. These operations return a 'view' of the original data. **c**, Indexing an array with masks, scalar coordinates or other arrays, so that it returns a 'copy' of the original data. In the bottom example, an array is indexed with other arrays; this broadcasts the indexing arguments before performing the lookup. **d**, Vectorization efficiently applies operations to groups of elements. **e**, Broadcasting in the multiplication of two-dimensional arrays. **f**, Reduction operations act along one or more axes. In this example, an array is summed along select axes to produce a vector, or along two axes consecutively to produce a scalar. **g**, Example NumPy code, illustrating some of these concepts.

NumPy is the base of the scientific Python ecosystem

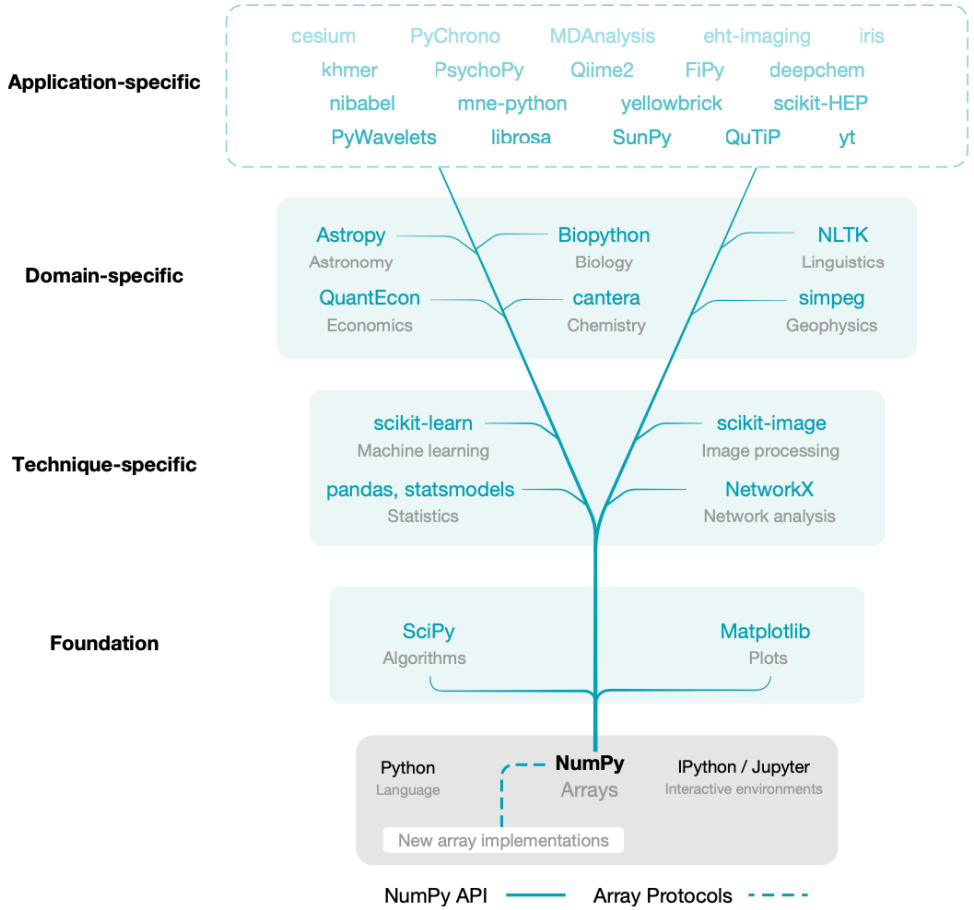


Fig. 2 | NumPy is the base of the scientific Python ecosystem. Essential libraries and projects that depend on NumPy's API gain access to new array implementations that support NumPy's array protocols (Fig. 3).

NumPy Image Analysis

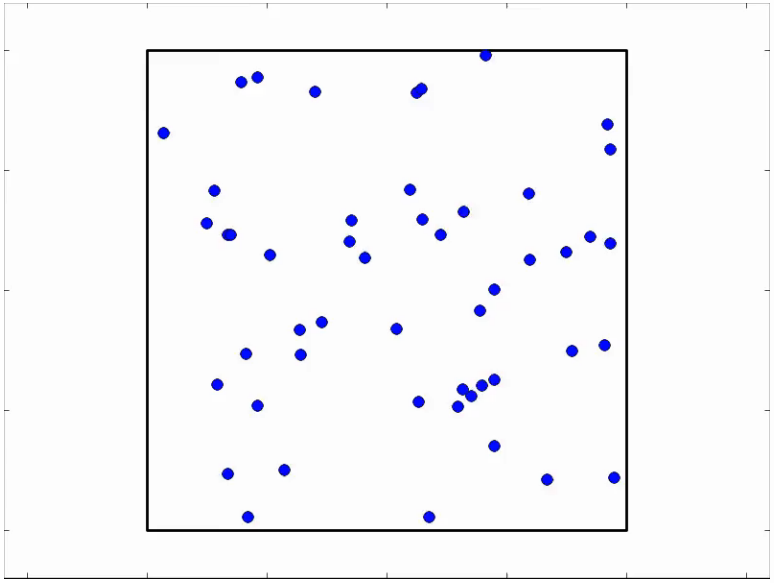
If the image is colored, then each pixel is represented by three numbers - a value for each of red, green, and blue. In that case we need a 3rd dimension (because each cell can only contain one number). So a colored image is represented by an ndarray of dimensions: (height x width x 3).

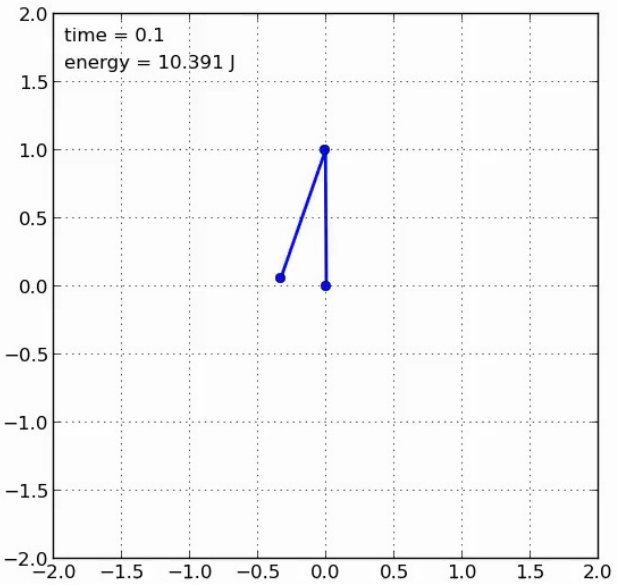
Source: https://jalammar.github.io/visual-numpy/

Animation

Created animated visuals using Matplotlib

Example Animations





Source: https://jakevdp.github.io/blog/2012/08/18/matplotlib-animation-tutorial/

FuncAnimation

matplotlib.animation.FuncAnimation

class matplotlib.animation.**FuncAnimation**(*fig*, *func*, *frames=None*, *init_func=None*, *fargs=None*, *save_count=None*, *, *cache_frame_data=True*, **kwargs*) [source]

Makes an animation by repeatedly calling a function *func*.

Note

You must store the created Animation in a variable that lives as long as the animation should run. Otherwise, the Animation object will be garbage-collected and the animation stops.

fig : plt.figure()
func : The animation function – called each frame
frames : The number of frames
fargs : Additional arguments to func (if needed)
interval : Time (ms) between frames

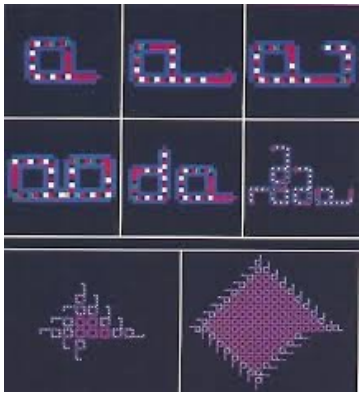
Artificial Life

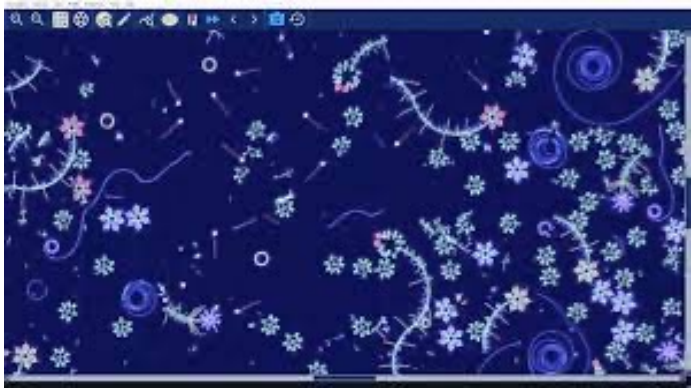
Life as it could be

Artificial Life Defined

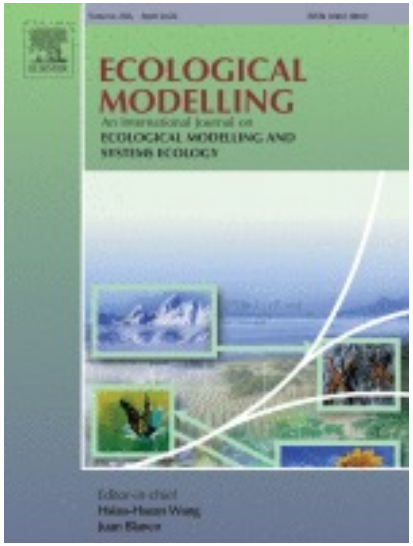
Artificial life (often abbreviated **ALife** or **A-Life**) is a field of study wherein researchers examine systems related to natural life, its processes, and its evolution, through the use of simulations with computer models, robotics, and biochemistry.

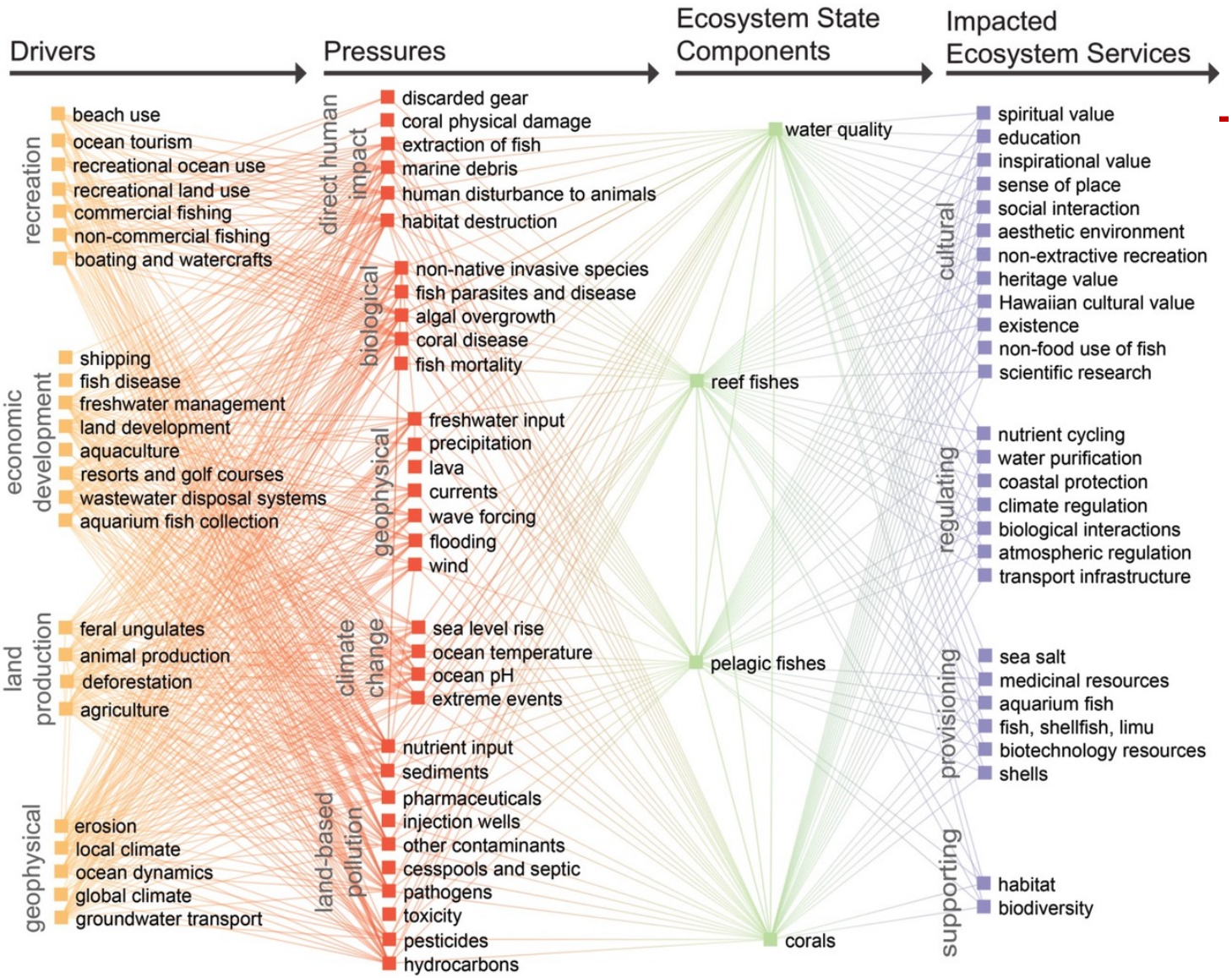
The discipline was named by Christopher Langton, an American theoretical biologist, in 1986.





Ecosystems





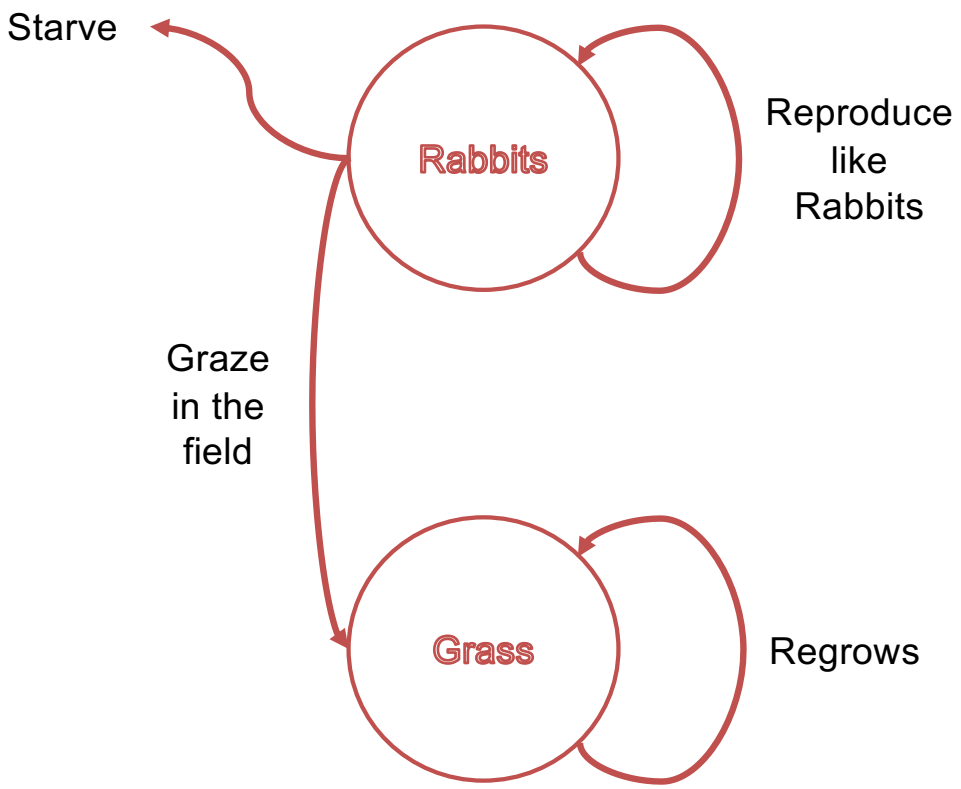
Northeastern University

Conceptual Models

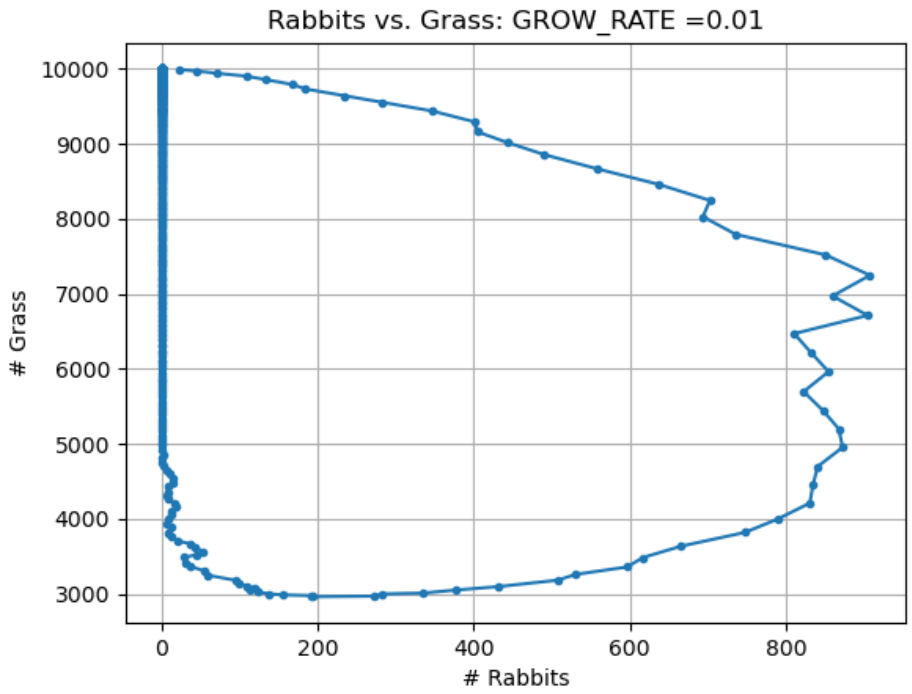
A **conceptual model** identities the qualitative (rather than quantitative) relationships among the various entities, suggesting causal connections without precisely defining the nature of the relationships in precise mathematical terms.

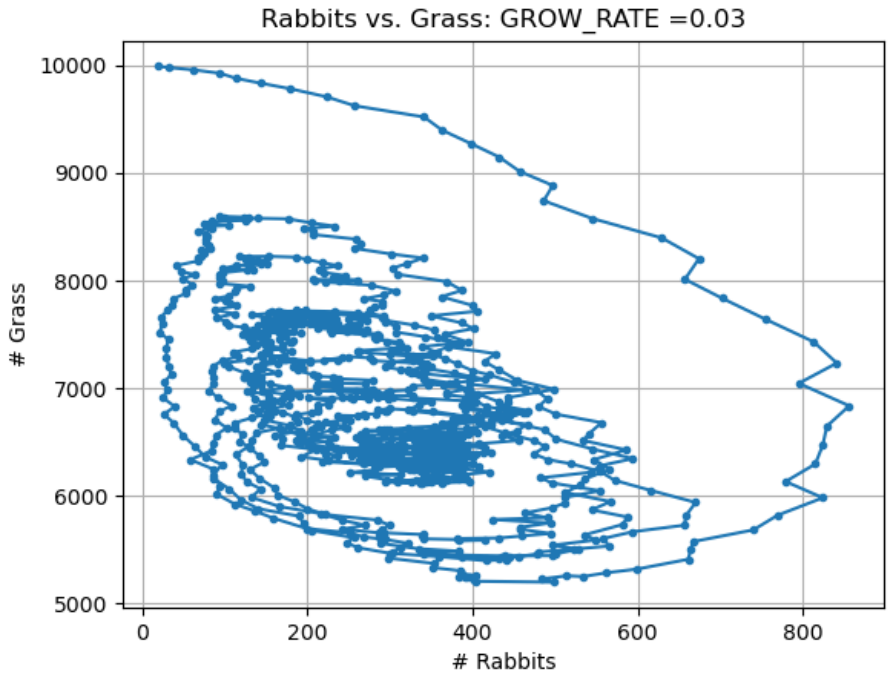
The conceptual model may serve as a starting point for understanding the underlying dynamics of **complex systems**.

From the study and simulation of conceptual models, more quantitative mathematical models may emerge. Until then, **simulation** may be used to validate the underlying assumptions of the conceptual model or to explore possible **emergent phenomena** or the **stability** of the underlying system.

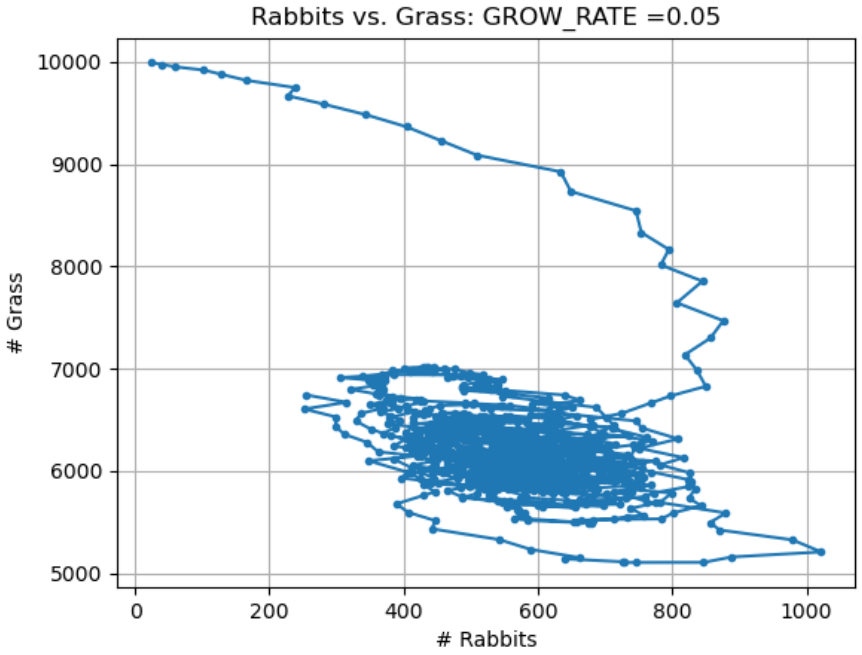


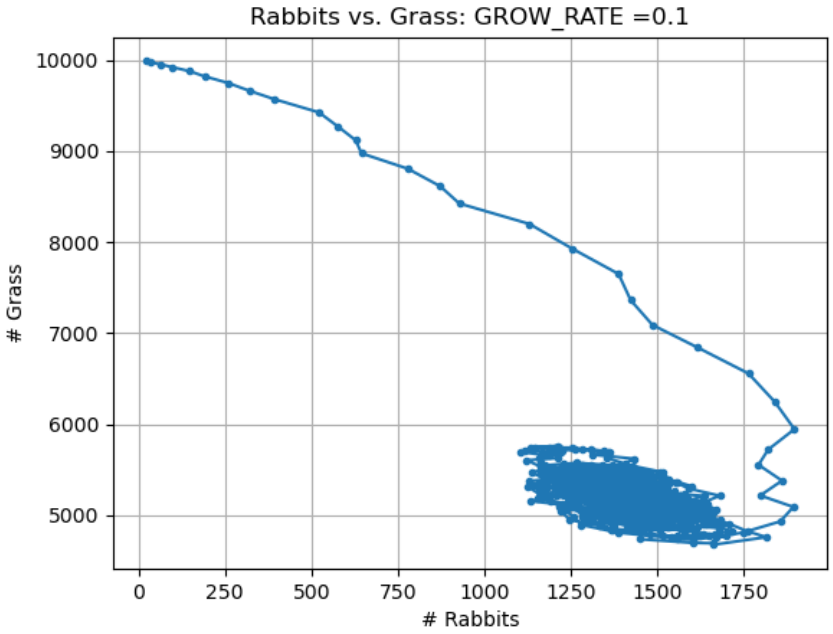
Rabbits vs. Grass



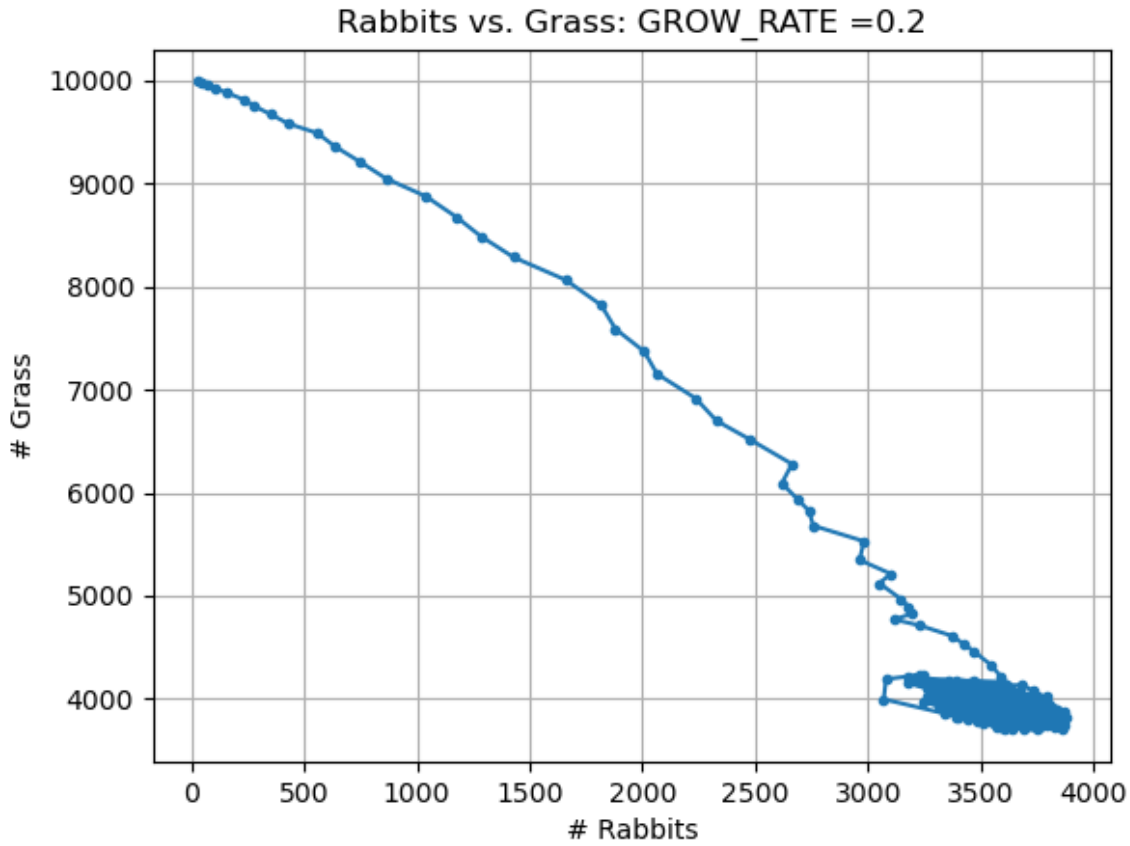


Rabbits vs. Grass

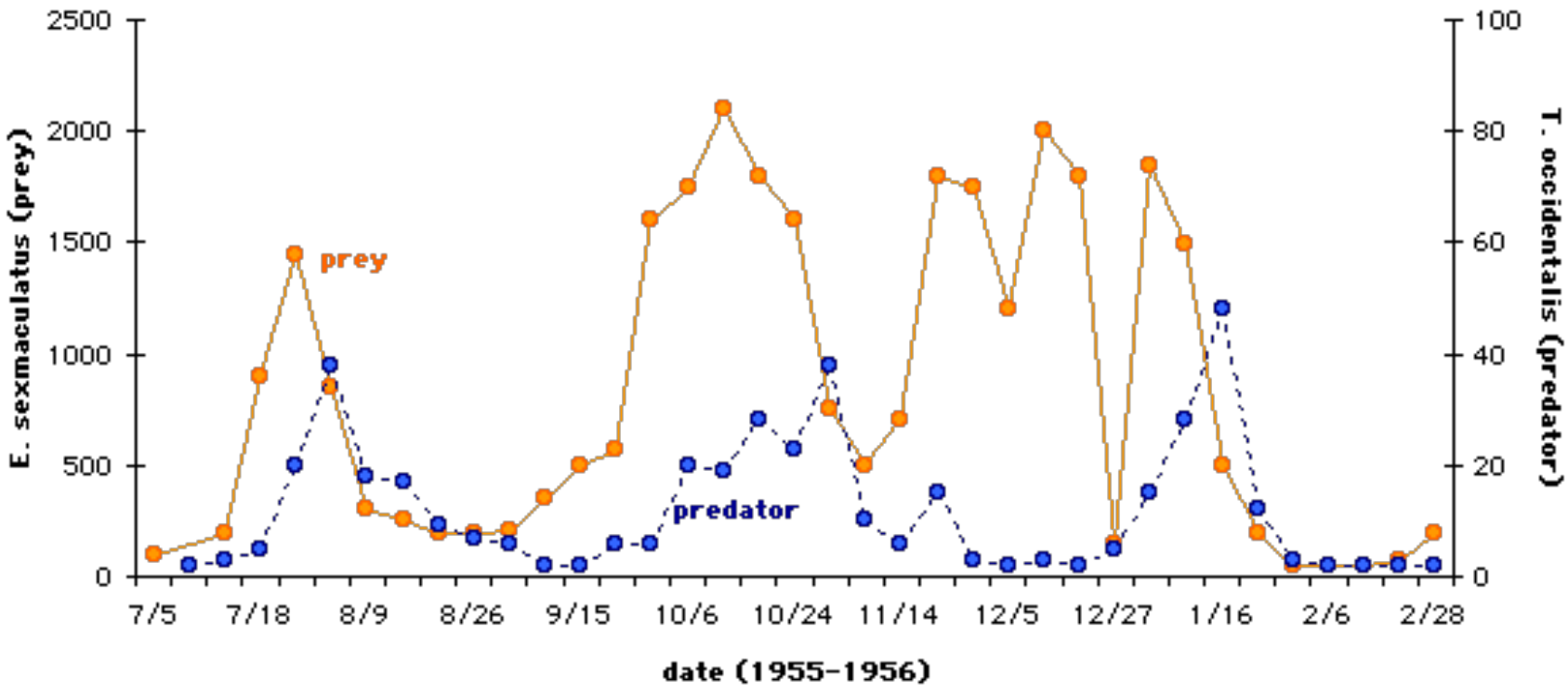




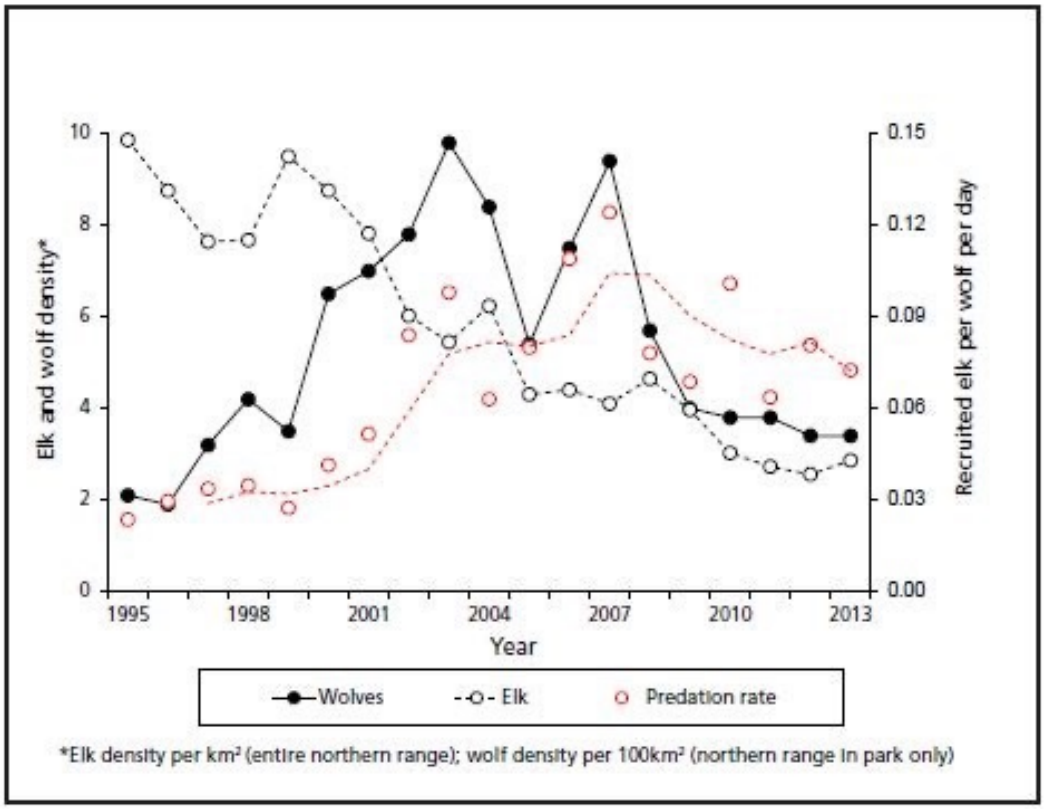
Rabbits vs. Grass



Mite vs. Mite


2500
2000
1500
1000
500
0
E. sexmaculatus (prey)
prey
predator
100
80
60
40
20
0
T. occidentalis (predator)
7/5
7/18
8/9
8/26
9/15
10/6
10/24
11/14
12/5
12/27
1/16
2/6
2/28
date (1955-1956)

Wolves vs. Elk in Yellowstone National Park



Lotka-Volterra Equations

$$\frac{dx}{dt} = \alpha x - \beta xy,$$
$$\frac{dy}{dt} = \delta xy - \gamma y,$$

where

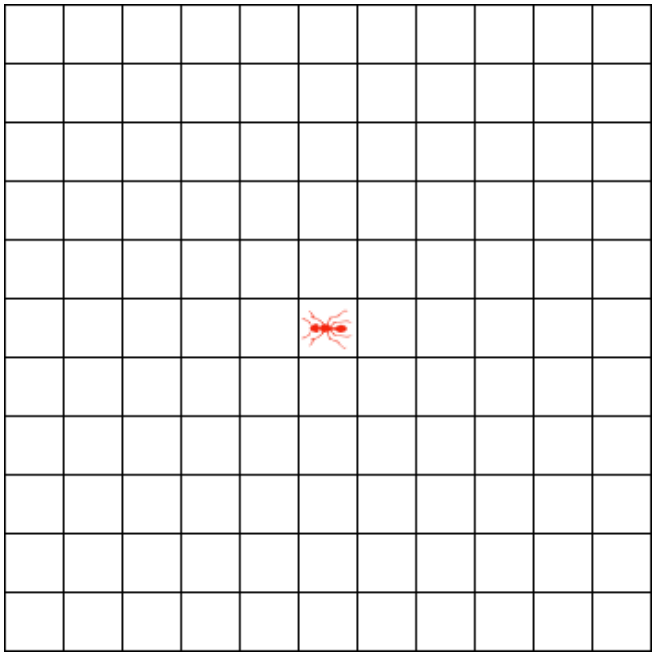
- x is the number of prey (for example, rabbits);
- y is the number of some predator (for example, foxes);
- $\frac{dy}{dt}$ and $\frac{dx}{dt}$ represent the instantaneous growth rates of the two populations;
- t represents time;
- α, β, γ, δ are positive real parameters describing the interaction of the two species.

Langton's Ants

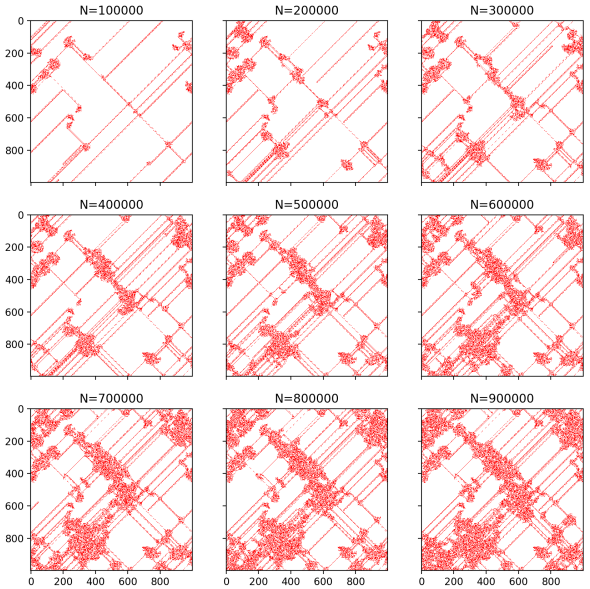
Modeling ants responding to pheromone signals.

An example of how the repeated application of simple rules → complexity

White: Turn Right, **Red**, 1 Step. **Red**: Turn Left, **White**, 1 Step



Langton's ant after 11,000 steps. A red pixel shows the ant's location.



Simulation and Modeling with Discrete Random Variables

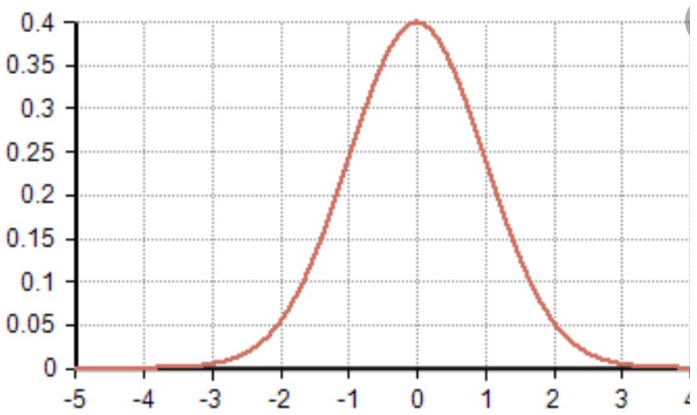
J. Rachlin
Northeastern University

Please build our town a bridge!

The cost is **$25 million**.
Guaranteed!

Please build our town a bridge!

The expected cost is **$20 million**.
I'm 95% sure it will cost
between $10-$30 million.



Please build our town a bridge!

The *expected cost* is just **$15 million**.
and most likely we can do it for $5 million!

***Translation**: If we built you 1000 bridges the average cost would be $15 million.*

p=0.95: cost = **5 million**
p=0.05: cost = ***205 million*** ***<<ouch!>>***

Avg Cost = (0.95)(5) + (0.05)(205) = 15

Auto Insurance

Plan	Premium	Deductible	Expected Cost P(accident)=0.05
A	$100	$500	$1225
B	$80	$1000	$1010

Plan A: 0.95 (12 x $100) + 0.05 (12 x $100 + $500) = $1225

Plan B: 0.95 (12 x $80) + 0.05 (12 x $80 + $1000) = $1010

Is Plan B necessarily the better plan for you?
Can you afford the larger deductible?
What is your tolerance for *risk?*

Risk and Uncertainty in Business Decision-Making

Should we acquire this company?

Should we hire this candidate and if so, at what salary?

Should I accept this investment offer for
5% of my company?

Should we move our data center to the cloud?

Can we upgrade our manufacturing facility?

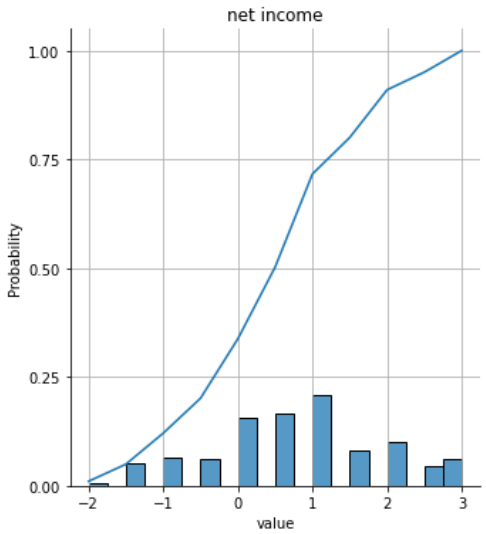
How much should we spend on advertising?

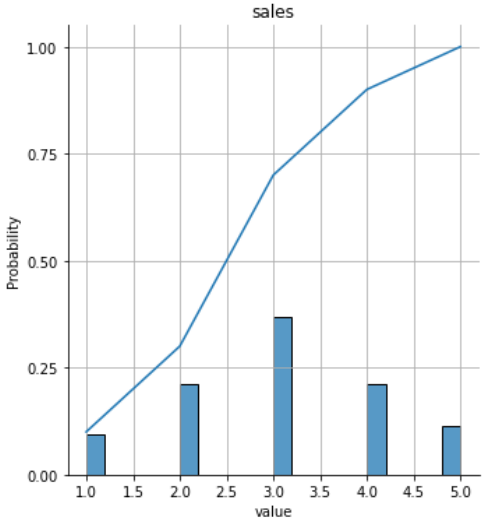
Should we focus on profits or growth?

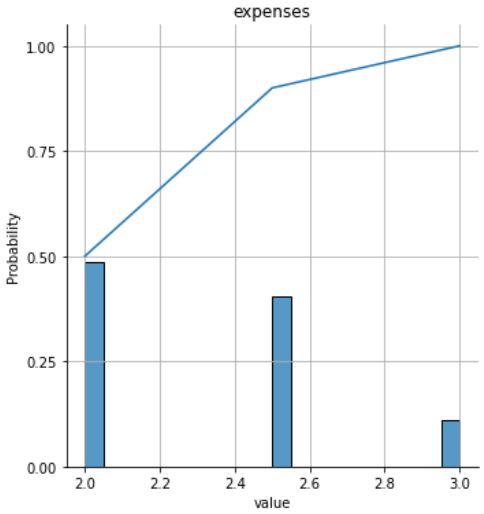
What products should we stock?

Business Forecasting: Net Income

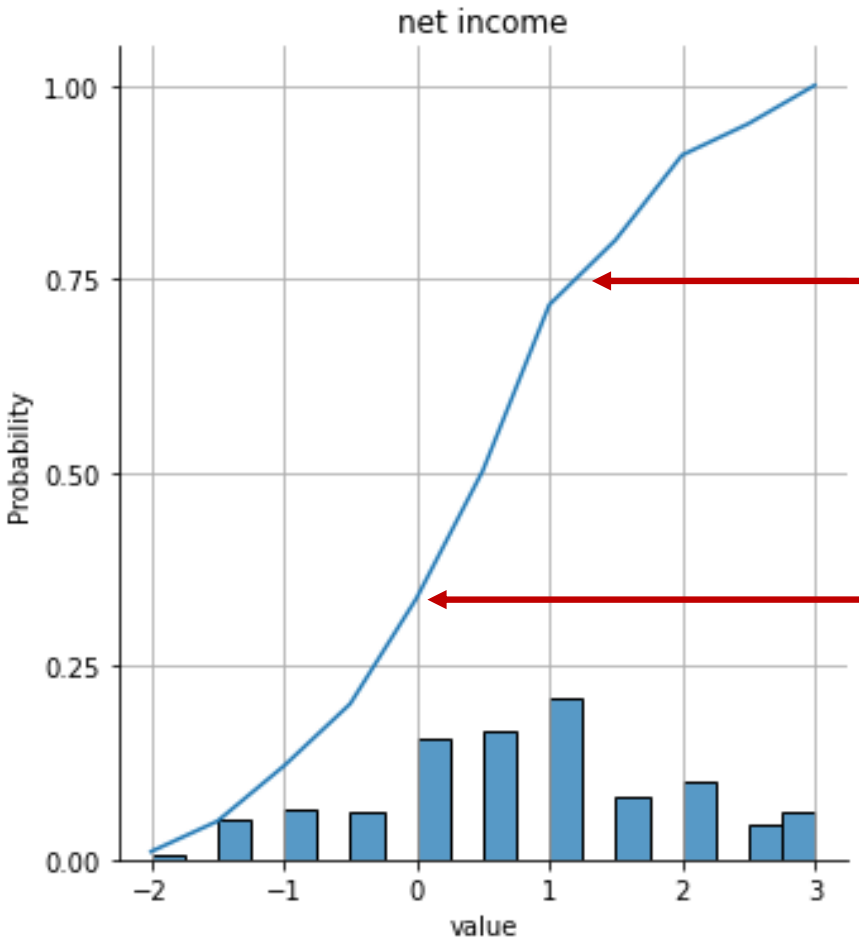
Net Income	**=**	**Sales**	**-**	**Expenses**
0.7 Billion	=	3.0 Billion	-	2.3 Billion







Business Forecasting: it's complicated

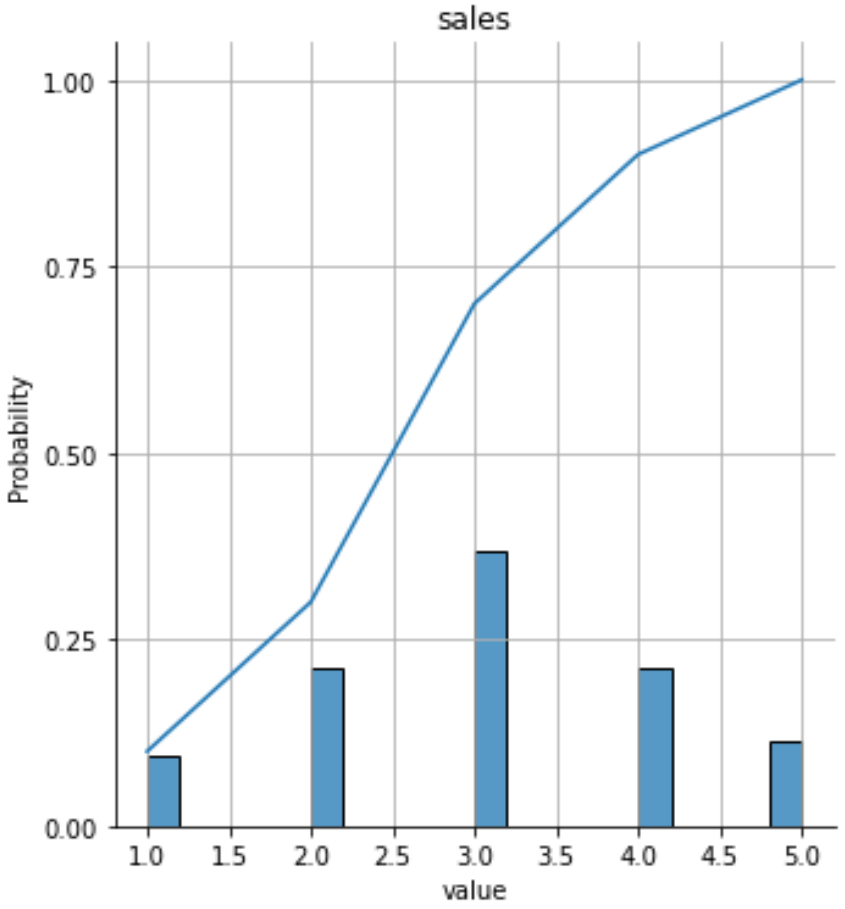


There is about a 25% chance
of making more than $1.1 million

There is about a 35% chance
of being unprofitable next year!

Random Variables

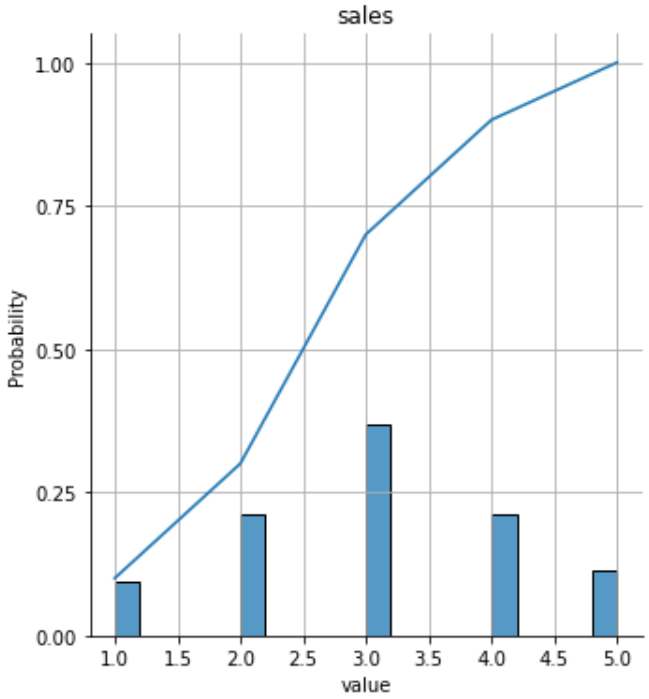
sales =



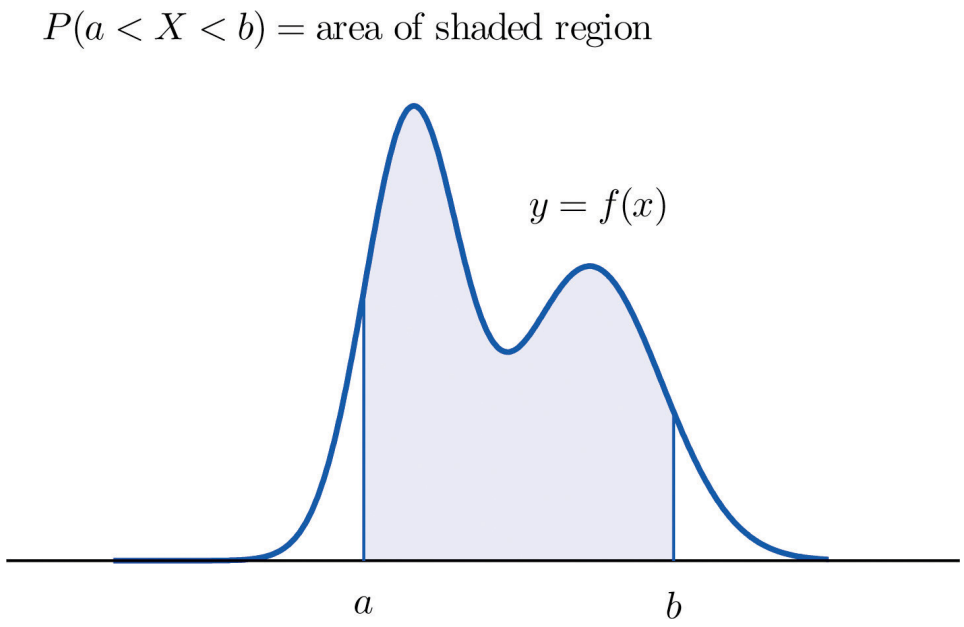
Sales is not a single number.
It's a *probability distribution!*

It takes on different values, each with a specified probability.

Discrete and Continuous Random Variables

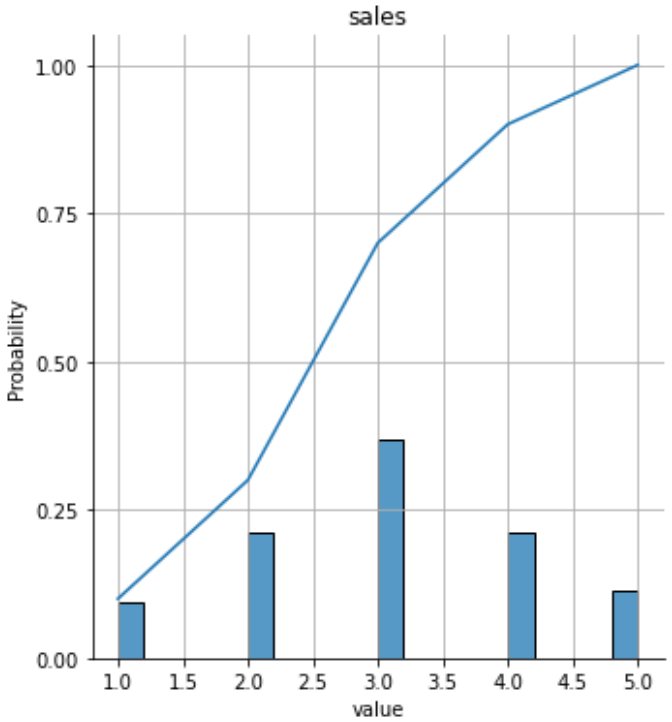


Discrete



Continuous

Discrete Random Variables are objects!



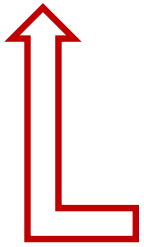
The distribution stored inside the object is simply a dictionary where:

Keys are **outcomes**
Values are **probabilities** that add to 1.0

```
{
 1:.10, 2:.20, 3:.40,
 4:.20, 5:.10
}
```

Mathematical expressions are now *simulations*!

sales	-	**expenses**	=	**net income**
5	-	2	=	3
4	-	2	=	2
3	-	2.5	=	0.5
3	-	2	=	1
2	-	3	=	-1
.				
.				
etc.				



A new discrete random variable!

But a simulation isn't necessary if …

- our random variables are *discrete*
- they represent *independent* events: p(**X** and **Y**) = p(**X**) p(**Y**)

Y

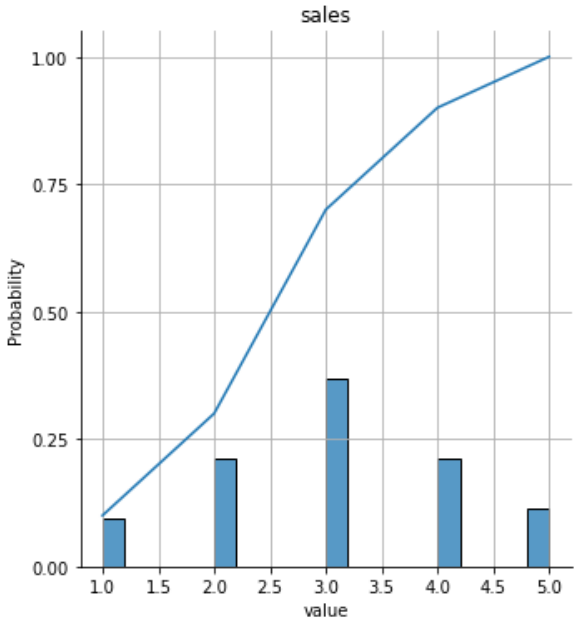
X	**0 (.20)**	**2 (.50)**	**5 (.30)**
1 (.60)	1 (.12)	3 (.30)	6 (.18)
3 (.40)	3 (.08)	5 (.20)	8 (.12)

← **Z = X + Y**

Expected value of X, denoted as E[X].

The expected value is basically a weighted average.
We are weighting each possible value by its probability.

`E[sales] = 1(0.1) + 2(0.2) + 3(0.4) + 4(0.2) + 5(0.1) =` **`3.0`**



$$E[X] = \sum x_i p(x_i)$$

x_i = The values that X takes

$p(x_i)$ = The probability that X takes the value x_i